UNIVERSIDADE CATÓLICA PORTUGUESA

A NEW CHEMISTRY OF SOUND:
THE TECHNIQUE OF MULTIPHONICS AS A COMPOSITIONAL ELEMENT
FOR GUITAR AND AMPLIFIED GUITAR

Thesis submitted to the Portuguese Catholic University to obtain the degree of
Doctor of Philosophy in Science and Technology of the Arts
Area of expertise: Computer Music

by

Rita Luzes Torres

ESCOLA DAS ARTES

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Volume 1

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Abstract

Due to lack of tone colour research on the guitar, the technique of multiphonics was investigated on this instrument. It was part of a strategy of presenting non-guitarist composers with new results from the exploration of unconventional performance techniques. Colour research on the guitar is usually carried out by such composers but these tend to dismiss the instrument. If, enticed by these results, they consider composing for guitar, the research's aim of contributing to the promotion of colour research on this instrument and to the establishment of multiphonics as part of its vocabulary would be fulfilled.

The technique of multiphonics consists, like the technique of harmonics, in damping out some of the vibrational modes of the string by lightly touching it at certain locations during or after its excitation (or both). Unlike with the technique of harmonics, the filtering of the vibrational modes is not systematic with respect to mode number, for which it is easier to perceive multiple pitches, of which some may be quite soft. The technique has yet to be absorbed into the guitar's vocabulary, possibly because it only recently received renewed attention. The information that is provided in the recent scientific literature is, however, limited. Moreover, it ignores the influence of the differences that may exist between players/instruments, it does not always take psychoacoustics into account, and it does not explore the amplification of the sounds, a gap that was also verified in the artistic literature.

Testing was therefore carried out to determine the influence of amplification on the audibility of the softer main components of the sounds. It consisted in recording with close microphone placement a sample of guitarists playing on their guitars a set of takes of the lowest string lightly touched at a myriad of established locations, and left to vibrate. The recordings were then spectrally analysed and the data was treated and evaluated taking psychoacoustics into account. The results show that the amplification with close microphone placement of sounds of guitar multiphonics introduces novelty to an audience relatively to the non-amplified instrument, regardless of room size. The results and assumptions based thereon were implemented in a piece for amplified guitar and live electronics, and in a guitar piece for which artistic research was carried out, leading to a new form of multiphonics usage.

Kewords: extended techniques, guitar, guitar multiphonics, guitar music, multiphonics, virtual frets.

Resumo

A guitarra encontra-se a um nível inferior relativamente a outros instrumentos no que respeita à pesquisa tímbrica. Esta situação pode ser explicada pela falta de interesse pelo instrumento da parte de compositores não-guitarristas, visto serem estes compositores os que geralmente efectuam aquele tipo de pesquisa. As limitações sonoras da guitarra e um certo desagrado pelo seu som paradigmático são duas das razões do seu desinteresse. Apresentar aos compositores que dispensam a guitarra por estas razões novos resultados provenientes da investigação de técnicas não-convencionais poderia eventualmente aliciá-los a considerar a escrita para guitarra, já que estas técnicas não só produzem sons com timbres pouco usuais mas também poderão ser úteis, por si só ou em combinação com outras técnicas, para ultrapassar limitações sonoras. Entre estas técnicas encontra-se a de multifónicos que ainda está por integrar no vocabulário da guitarra, possivelmente porque apenas recentemente foi alvo de atenção renovada. Estas recentes pesquisas foram, no entanto, realizadas no âmbito de projectos de um contexto mais alargado, pelo que a informação que delas resultou é limitada. Para além disso, esta informação é baseada na execução de um único guitarrista, essencialmente numa única guitarra, ignorando as diferenças que poderão existir entre instrumentistas/guitarras. Acresce que questões de psicoacústica nem sempre foram consideradas. Assim, deu-se início a uma investigação exaustiva da técnica de multifónicos na guitarra, da qual esta tese foi o ponto de partida, por forma a mostrar à comunidade artística um maior leque de possibilidades da técnica, e a providenciá-la com informação relevante, o que deverá fomentar a utilização da técnica e levar compositores não-guitarristas a pesquisá-la também, satisfazendo o objectivo da investigação de contribuir para a promoção da pesquisa tímbrica na guitarra e para a integração da técnica de multifónicos no seu vocabulário.

O primeiro passo da investigação foi uma cuidada análise teórica da técnica do ponto de vista acústico e psicoacústico, com vista à sua melhor compreensão e à elaboração de uma explicação detalhada que não existia na literatura. A técnica de multifónicos consiste, tal como a de harmónicos, no abafamento de alguns dos modos de vibração da corda através de um leve toque em certos pontos da corda durante ou depois da sua excitação (ou ambos), e resulta melhor nas cordas com enrolamento. Ao contrário do que acontece com a técnica de harmónicos, a filtragem dos modos de vibração não é sistemática relativamente ao número do modo, dando origem a um som em que as frequências (quase) harmónicas de componentes vizinhos não se encontram todas igualmente espaçadas, o que facilita *a percepção de diversas notas. Os sons apresentam assim uma* química *diferente dos outros sons harmónicos complexos da guitarra. O seu volume sonoro máximo é contudo menor do que o dos sons convencionais e o volume sonoro relativo de alguns dos seus principais componentes pode ser bastante baixo. Apesar disto, nem os autores científicos nem os compositores que de quando em quando usaram a técnica, exploraram a amplificação dos sons. O que levou a perguntar se esta traz novidade a um público – caso contrário, não faz sentido usar a técnica de multifónicos na actuação ao vivo com guitarra amplificada, pois o ouvinte poderá conotar o som com o do instrumento não-amplificado e ficar decepcionado. Foi então formulada a hipótese de a amplificação de sons de multifónicos com o microfone a curta distância trazer novidade a um público, pois, caso contrário, este não conseguiria percepcionar alguns dos componentes principais dos sons, independentemente do tamanho da sala.*

A hipótese foi testada numa experiência em que uma amostra de guitarristas foi gravada com o microfone a curta distância a tocar nas suas guitarras um conjunto de takes *do leve tocar da corda mais grave em pontos previamente estabelecidos, deixando depois a corda vibrar. Estes pontos encontram-se não só em trastos como também em* trastos virtuais*, isto é, em pontos entre trastos, fáceis de situar visualmente – o que nem sempre é considerado na literatura e poderá diminuir a reprodutibilidade dos sons. As gravações foram analisadas espectralmente e os dados foram tratados e avaliados tendo em conta questões de psicoacústica. Os resultados mostram que a hipótese é verdadeira mas apresentam certas limitações, como, por exemplo, o facto de poderem não ser válidos se, em vez de ser usado um microfone de alta sensibilidade como o da experiência, for usado um com uma sensibilidade mais baixa.*

Os resultados e suposições feitas a partir deles foram implementados em duas peças musicais: uma para guitarra e outra para guitarra amplificada e electrónica em tempo real. Para a primeira, foi ainda realizada investigação artística, o que levou uma nova forma de utilização dos sons de multifónicos. Estes sons foram notados de forma diferente nas partituras das duas peças, pois são usados em contextos sonoros distintos.

Palavras-chave: *guitara, multifónicos, multifónicos na guitarra, música para guitarra, técnicas extendidas, trastos virtuais.*

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% per cent

‰ per mille

ca. *circa* (approximately)

cf. *confer* (compare)

chap. chapter

cm centimeter(s)

dB decibel(s)

dBA decibel(s) A-weighting

e.g. *exempli gratia* (for example)

feasib. Feasibility

FFT Fast Fourrier Transform

Fig. / Figs. Figure(s)

freq. / freqs. frequency (frequencies)

guit. guitar

Hz Herz

i.e. *id est* (that is)

ID identification

IRCAM Institut de Recherche et Coordination Acoustique/Musique

l.m.p. Loudest main partial

loc. / locs. location(s)

loc./p. location/partial [in Appendices' tables]

max. maximum

min. minimum

mm millimetre(s)

mod. moderately

ms millisecond(s)

mV millivolt(s)

n/a not applicable/available, no answer

no. / nos. number(s)

o.v. original version [for translations]

p. / pp. page(s)

Pa Pascal

para. paragraph

r.d. / r.ds. relative distance(s)

r.l. / rls. relative loudness(es)

r.l.d. / r.l.ds. relative loop displacement(s)

s second(s)

s.d. standard deviation

t.s. time segment

var. variant

v.f. / v.fs. virtual fret(s)

v.m. / v.ms. vibrational mode(s)

Notes for the reader

All quotations from foreign languages were translated by the author. The original version is supplied in a footnote. Quotations from radio broadcasts were transcribed from podcasts no longer retrievable from the web.

The term *data* is used as a mass noun (and not as plural of *datum*).

The terms *harmonics* and *multiphonics* are used to refer the techniques of harmonics and of multiphonics, respectively. When they are subjects in a phrase, however, they are always used in the expressions *the technique of harmonics* and *the technique of multiphonics*, respectively, since they are not established as mass nouns. In order to avoid confusion between a sound resulting from the technique of harmonics, a sinusoidal component of a sound, and a harmonic complex tone, the term *harmonic,* (and, for coherence, the term *multiphonic*) is not used (except in quotations). A sinusoidal component of a sound will be referred to either as *partial*, or *fundamental/overtone*. The term *vibrational mode* is used for the physical movement that gives rise to a partial.

The nut and the saddle are the rest points of the guitar strings, respectively at the neck and at the bridge. The term *fret* is used only for the metal strips on the neck (it is usually also used for the spaces between each strip). Each space between strips is numbered after the number of its enclosing strip that is closest to the saddle, which is notated with a roman numeral.

The quality of vitality that makes any culture significant involves …
investigation, investigation, investigation.
Harry Partch[1]

[1] In H. Partch, *Genesis of a music*, p. xv

1 Introduction

The guitar lags behind other instruments in tone colour research.[2] This situation can be explained by a lack of interest in the instrument by non-guitarist composers, since colour research on the guitar is usually carried out by such composers. Among the reasons for their dismissal of the guitar are its sonic limitations and a certain dislike for its paradigmatic sound. Composers who dismiss the instrument for these reasons could be enticed to consider composing therefor by being presented with new results from the exploration of unconventional performance techniques, because these techniques not only give rise to sounds of unusual colours but, alone or combined with other techniques, can also be useful in overcoming sonic limitations. One of these techniques is that of multiphonics, which has yet to be absorbed into the guitar's vocabulary, possibly because it only recently received renewed attention. These recent researches were, however, carried out in the context of projects of larger scope, for which the information supplied is limited. Moreover, part of it is based on the execution of a single guitarist playing mostly a single instrument, thus it ignores the influence of the differences that may exist between players/instruments. Furthermore, psychoacoustics was not always considered. Therefore, a thorough investigation of multiphonics was initiated with this thesis, in order to show the artistic community a wider range of possibilities of the technique, and to provide it with relevant information. This should increase the usage of multiphonics, leading non-guitarist composers to carry out further research, which would fulfil the investigation's aim of contributing to the promotion of colour research on the guitar and to the establishment of multiphonics as part of its vocabulary. A detailed contextualisation and justification of this research can be found in Chapter 2.

The first step of the research was to theoretically scrutinise the acoustics and psychoacoustics of multiphonics, in order to better understand it and provide a detailed explanation thereof (included in Chapter 2), which lacked in literature. The technique of multiphonics consists, like the technique of harmonics, in damping out some of the vibrational modes (v.ms.) of the string by lightly touching it at certain locations during or after its excitation (or both). Unlike with harmonics, the filtering of the v.ms. is not systematic with respect to mode number. This gives rise to a sound

[2] The term *colour* (or *timbre*) is used here to refer to the sound quality produced by a single instrument, and not to “the quality of the sound produced by a given combination of instruments in terms of their instrumental color and the way in which they produce pitches together” (Lansky, 1974, p. 741). This belongs to the category of *texture*, which, according to Truax (1992, p. 34), is perceived when the sound sources occur within 50 ms; otherwise they are perceived as detached events.

in which the (almost) harmonically related frequencies of neighbouring components are not all equally spaced, which makes easier the perception of multiple pitches. The sounds present then a *chemistry* different from the guitar's other complex harmonic tones. Their maximum overall loudness is, however, lower than conventional sounds, and the relative loudness of some of their main components may be quite low. Notwithstanding, scientific authors did not explore the amplification of the sounds, nor did the composers who now and then made use of the technique. This led to ask if the amplification of the sounds introduces novelty to an audience, because otherwise it does not make sense to use the technique in live performance of the amplified guitar, as the listener may connote it with the non-amplified instrument and be disappointed. An experiment was then conducted to test the hypothesis that the amplification of sounds of multiphonics with close microphone placement introduces novelty to an audience, because the audience would otherwise not perceive some of the sounds' main components, regardless of room size.

The methodology and method of the experiment and the methodology of the implementation of its results in two musical compositions are discussed in Chapter 3 (the scores of the pieces are included in Volume 2). Three kinds of research are possible in the area of arts and technology: “applied research that is initialized as part of a specific artistic production or project, more fundamental research that follows the paradigm of scientific research, or the development of tools that are made to be used by others independently” (Goebel, 2009, p. 244). Although the work carried out consisted essentially in fundamental research, applied research – more concretely, artistic research – was also carried out, leading to a new form of multiphonics usage. The fundamental research followed the paradigm of scientific research and had an interdisciplinary character, given that it had a "process of its own that involve[d] drawing on relevant disciplinary insights, concepts, theories, and methods ... to create an integrated and purposeful result" (Repko, 2012, pp. 10, 16). Testing consisted in recording a sample of guitarists playing on their guitars a set of takes of the lowest string lightly touched at established locations and left to vibrate. The recordings were then spectrally analysed, and the data was treated and evaluated taking psychoacoustics into account. Volume 2 contains the treated data and Chapter 4 summarises and discusses the results presented in the appendices. The results show the hypothesis to be true. A limitation to the finding is that it may not always be valid if, instead of a highly sensitive microphone like that of the experiment, a microphone of a lower sensitivity is used. Other main findings and limitations are summarised in Chapter 5, which also underlines the research's contribution and outlines future work.

2 A *New Chemistry of Sound* on the Guitar

The guitar ... disposes of a sonorous richness that is capable of encompassing everything a modern instrument possesses.
Hans Werner Henze[3]

In the third movement of *Fantasie Villageoise,* Fernando Sor (ca. 1832, pp. 8-9) asks for harmonics at fret VI, as in the third and fifth bars of the score excerpt of Fig. 2.1. This was an unusual request because fret VI was not used as a harmonics location, as Fig. 2.2 shows. There is, however, no doubt that this was Sor's intention because, as Gimeno (2011) notes, Sor notates the locations not situated at frets with dashes above or below the (Arabic) number of the closest fret (pp. A77-A78), like Aguado in his table of Fig. 2.2 (lower staff). Here, three sounds of harmonics are interestingly categorised as "obscure."[4] This is probably due to the damping of the higher partials by the greater finger pressure needed to play these sounds, or to the blurred tone that is perceived when a lighter pressure is applied. Sor had already stressed in his Guitar School (1830) that "in so far as the sounds to be produced required a position closer to the nut, the act of plucking should be more forceful, and the pressure of the left-hand finger stronger" (as quoted in Micheli, 2003, p. 57). A higher pressure is necessary because the node at which the touching takes place, which is shared by the vibrational modes (v.ms.) that give rise to the desired sound, is closely surrounded by nodes of other v.ms. A lighter pressure would not damp out these v.ms. giving rise to a sound of unusual colour, containing partials with a strength similar to that of the partials of the sound obtained with a higher pressure. This technique is nowadays usually called *multiphonics*, and is the only possible at fret VI, regardless of the touch pressure. With his request, Sor wanted most certainly to evoke the sound of bells, given that the movement is entitled *Prière* (Prayer) and the sounds are alternated with a melody set alone or harmonized in chorale fashion. He was then possibly the first composer to have requested multiphonics – albeit implicitly, since he does not allude to the unusual sound, nor does he notate resulting pitches –,[5] just one year after the first soloist concerts of six-string guitar took place.[6]

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[3] As quoted in P. Pfäffgen, *Die Gitarre: Grundzüge ihrer Entwicklung*, p. 204. Original version (o.v.): Die Gitarre ... verfügt über ein klanglichen Reichtum, der alles zu umfassen vermag, was ein modernes Instrument besitzt.

[4] These have as fundamental a partial higher than partial 7 of the open-string sound. On the cello, Devoto (2011) categorizes these kind of sounds of "distant harmonics" (p. 54).

[5] It was not common in Sor to notate harmonics with string and fret numbers and resulting pitch but, according to Gimeno (2011, p. A64), it is possible to find this in his Op. 60.

The technique of multiphonics had to wait 140 years until it was asked for again in a score and, today, it has yet to be absorbed into the guitar's vocabulary. Although the sounds possibly met the aesthetic ideal of some composers of the beginning of the twentieth century and onwards, the guitar was too small for the gigantism of turn-of-the-century romanticism. Moreover, the guitar faced prejudice aimed against it as an art-music instrument, which is a sentiment that still prevails to some extent today. Later, while other instruments were being scrutinised in the search for new colours, as discussed in section 2.1, the guitar was slowly coming out of the rule of conservative guitarist Andrés Segovia. This is still verified today despite the effort of more adventurous guitarists. These and other reasons have left the guitar behind other instruments in colour research. Those reasons are discussed in section 2.2, which also proposes ways to overcome the problem, one of them being the exploration of unconventional performance techniques, namely that of multiphonics. Section 2.3 revises existing literature, discusses its gaps, explains the technique, and formulates the research question.

2.1 Colour Research and the Extension of the Sonorous Possibilities of an Instrument

> As modern composers have gradually discarded the more conventional elements of music … tone colours have become one of the main weapons in the composers' armoury.
>
> Reginald Smith Brindle[7]

> The most sudden and important revolution to affect the musical world during the recent past was based not on some type of reflection upon musical grammar (serial or other), but rather —more deeply—upon the world of sounds themselves.
>
> Tristan Murail[8]

In the late eighteenth and early nineteenth centuries, instrument construction technology and performance practice had been in close alliance to aim at "the elimination of all but a narrow range of timbre variation, the promotion of stable and fixed pitch, fixed tuning and, perhaps most important, the virtual elimination (or at least minimisation) of noise components" (Emmerson, 2007, p. 104). Afterwards and up to the twentieth century, there were attempts in colour variation but these were "largely attempts to 'color' pitches" (Brooks, 1974, p. 340). In the beginning of the twentieth century composers started approaching composition based also on sound

[6] The concerts were played by Paganini in Paris (Miteran, 1997, p. 131). The first six-string guitars were constructed in the 1780s (Tyler & Sparks, 2002, pp. 219-222).

[7] In R. S. Brindle, *The new music*, p. 153.

[8] In T. Murail, The revolution of complex sounds, p. 121.

Figure 2.1. Score excerpt of the transition from the second to the third movement of Sor's *Fantasie Villageoise*

Reprinted from *Fantasie Villageoise* (p. 8.), by F. Sor, ca. 1832, Paris: the composer

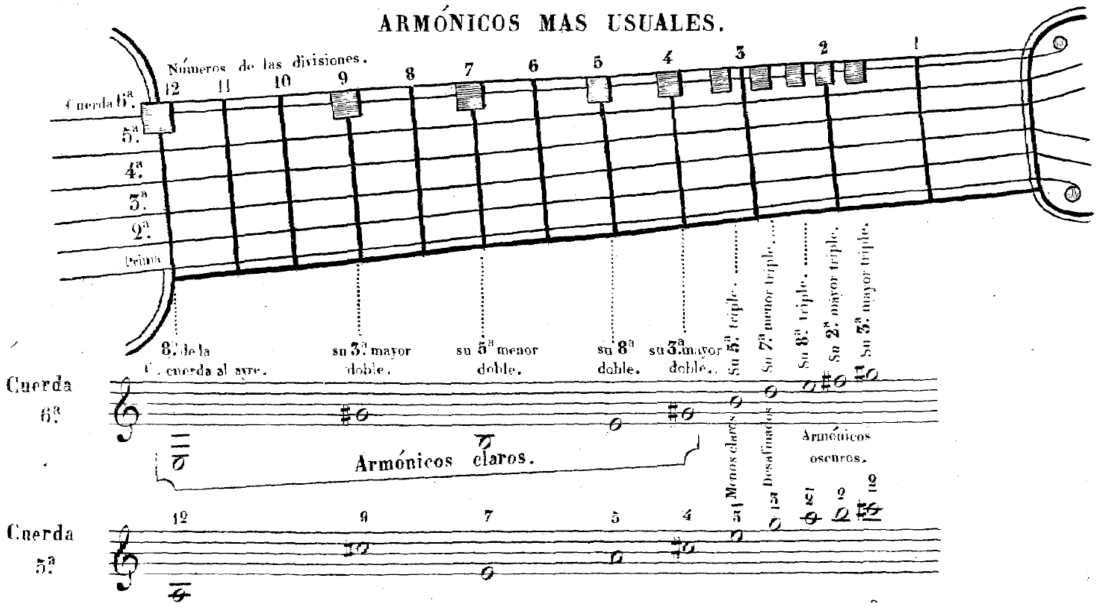

Figure 2.2. Excerpt of the harmonics table of Aguado's Guitar School

Reprinted from *Nuevo método para guitarra* (p. 54), by D. Aguado, ca. 1844, Paris: Schonenberger

and not only on notes, and colour started playing an important role.[9]

Colour research is mainly carried out by composers and performers, taking usually the form of artistic research. For Dautrey (2010), “the specificity of artistic or inventive research is maintaining all its tension in the product of its effort and imposing it to the one that confronts it” (p. 28).[10] She mentions two forms of artistic research, with origin in distinct epochs. The first is more subjective and absorbs the

[9] Landy (2007) defines *sound-based music* (or *sound-based art works* for the “non-Cageian reader” [p.241]) as “the art form in which sound, that is, not the musical note, is its basic unit” (p. 17). D'Escriván (2007) calls it “'organised sound' (to paraphrase Varèse) aesthetic: music structured around sound objects and their development, without necessary reference to melody or harmony” (p. 165).

[10] O.v.: La spécificité de la recherche artistique ou inventive est de maintenir toute sa tension dans le produit de son effort et de l'imposer à celui qui le regarde.

research in the realisation of the work, leaving the analysis of the research's steps to non-practicing specialists. This form arose in the nineteenth century as a reaction against the other form of research, which had originated in the academies and had been prevalent in the two previous centuries. This second form is more objective and often collective, making the research's steps public by sharing them with scientific or technical communities, and giving rise to an ensemble of common rules or objects (pp. 17-21). Leman (2003) also refers these two kinds of research. He relates the first, in which creative processes are exploited "using tools that allow flexible control and manipulation of musical materials", with exploratory research;[11] and the second with systematic research, a kind of research that "contributes to the understanding of the creation process through analysis of the creative context, observation of behavioral and neurophysiological processes, and the knowledge-based construction of tools for creative exploration" (p. 65). For Leman exploratory research is related with to "the romantic view ... that creativity cannot be educated; that it is independent from context, and that it must flow out of a divine or natural drive or emotional engagement and inspiration" (p. 66); and systematic research is based on the Enlightenment view of creation "as the outcome of a rational process and sometimes even as a mechanical process" (p. 67). Since the advent of technology and the institutionalised research environment, however, there is a mutual "fertilization" between these two "parallel roads", along which "musical creativity research" develops, points out Leman (p. 65). In fact,

> creation is no longer the invention of a good idea, nor is the exploration of a new tool. Rather it is a connected ensemble of invention, novelty, justification, realization, and communication of results, involving rational as well emotional processes. (Leman, 2003, p. 68)

This is also the view of Béros (2010, p. 153), for whom "musical research should not be mistaken for experimentation per se, indeterminate exploration, or personal invention."[12] Instead, it is the result of a process of interaction between the composer and a research environment, which should lead to generalisation and formalisation of results (which do not consist in the work of art), and which can only be validated by the realisation of a series of works. This is corroborated by composer Marco Stroppa: "musical research is the activity of reflection of the composer through an essentially verbal form of communication, which has the goal of generalisation, or

[11] Exploratory research aims "to generate significant findings about phenomena without appealing to a theory about these phenomena for the purpose of focusing experimental attention on a limited range of possible findings" (Waters, 2007, p. 5).

[12] O.v.: La recherche musicale ne se confond pas avec l'expérimentation pour soi, l'exploration indéterminée ou l'invention particulière.

even modeling" (Béros, Dautrey, Donin & Stroppa, 2010, p. 184).[13] Stroppa's researches start by "ripping off" a process from the intuitive sphere due to necessity of formalising it in order to better understand how it works. This leads him to the creation of models which can then be used for the generation of new materials and the analysis of existing ones – contexts different from those in which they were initially conceived. An "epistemological" basis is thus given to the environment in which his artistic thinking will continue to develop, which might as well be in collaboration with the scientific community (Béros, Dautrey, Donin & Stroppa, 2010, pp. 177-178, 182, 183).

Collaboration with the scientific community (and the use of state-of-the-art technology) became possible, or at least facilitated, with the institutionalisation of musical research, in which the artistic avant-garde played an important role (Leman, 2003, pp. 70-71). The institutionalised musical research involves an infrastructure, division of labour, and an artistic paradigm implying "a particular methodology, which guides creative thinking, and it often will impose a stylistic idiom, a kind of musical world view, a typical sound as well"; moreover, the organisation of artistic research follows that of scientific research (Leman, 2003, pp. 71-73). The kind of interaction Stroppa has with scientists is one in which both him and scientist have enough knowledge of each other's fields in order to propose solutions to one another. He mentions, however, two other kinds of composer-collaborators: the "absolute-master composer",[14] who does not try to understand the scientific thinking but has a good intuition of what research can do; and the "composer-in-research", who works with a scientific team, understands the research, and, as the "super poetic-aesthetic consultant",[15] is the only one who can validate its musical potential (Béros, Dautrey, Donin & Stroppa, 2010, pp. 184-185). As with every kind of research, serendipity plays a role in artistic research, and may even be fostered by computer tools (Leman, 2003, p. 72) if, according to Boulez, there is enough flexibility:

> Musical invention must bring about the creation of the musical material it needs; by its efforts, it will provide the necessary impulse for technology to respond functionally to its desires and imagination. This process will need to be flexible enough to avoid the extreme rigidity and impoverishment of an excessive determinism and encompass the accidental or unforeseen, which it

[13] O.v.: La recherche musicale est l'activité de réflexion du compositeur sous une forme communicable (essentiellement verbale), avec une volonté de généralisation, voire de modélisation.

[14] O.v.: Compositeur maître absolut

[15] O.v.: Super consultant poético-esthétique

> must be ready later to integrate into a larger and richer conception. (Boulez, 1978, p. 61)

Technology is, in fact, one way by means of which new colours may be achieved. Subsections 2.1.1 to 2.1.3 discuss this and the other ways in which colour research was carried out in the twentieth century. Subsection 2.1.4 presents the specific case of multiphonics.

2.1.1 Colour contrasts and unconventional sound-sources

The twentieth century witnessed an acceleration in the pace of the search for new colours. In the beginning of the century, the "increasingly frenetic search for novel instrumental possibilities has been due primarily to a need for colour contrasts", notes Brindle (1987, p. 153). This author mentions three ways in which colour/texture contrasts were used in the first half of the twentieth century:

1. Instruments of contrasting timbre succeed each other in the playing of few notes (pointillist style).
2. Contrasting textures dominate in turn entire sections of a composition.
3. The tonal possibilities of a single instrument are exploited (Brindle, 1987, pp. 153-154).

This latter case, which is discussed in section 2.1.2, gave rise to a preference for, and increased use of, solo instruments and mixed ensembles.

More adventurous composers achieved new colours by making use of unconventional sound-sources. In 1913, the futurist painter Luigi Russolo wrote the manifesto *The Art of Noises* and turned it into reality by creating the *intonarumori* (noise producers), and performing concerts with his futurist comrades in some European cities (Holmes, 2008, pp. 12-17). This caught the attention of composers such as Edgar Varèse who made extensive use of percussion noises. This "render[ed] a service by opening a wide field for investigation", stresses Cowell (1929/2004), for whom the result thereof will be "a new chemistry of sound" (p. 24). According to Marco (2002), Varèse's *Ionisation* (1931) is the first individual piece (i.e., not as part of a larger work) scored for percussion alone (p. 286). It features instruments that had usually a secondary role, and unconventional instruments such as the siren, of which George Antheil had made use along with airplane propellors in his *Ballet Mécanique* (1924). Later, unconventional sounds would stem from ancient and non-European instruments (Von der Weid, 1997, p. 264).

2.1.2 Unconventional performance techniques and new or modified instruments

New sonorous materials were also the result of a better exploration of conventional sound-sources. Arnold Schönberg's *Sprächgesang* in Pierrot Lunaire (1912) is an early example of this kind of research. Another pioneering example is Henry Cowell's strumming, scraping, and plucking of the piano strings, dating the first pieces from the 1920s (Burtner, 2005, para. 5). The influence of Cowell led John Cage to inserting objects between, or placing them on, the strings, presenting a case where "extended performance techniques ... may produce sounds of perceptually uncertain origin" (Emmerson, 2007, p. 129). *Sonatas and Interludes* (1946-48) is one example of Cage's compositions for prepared piano (Brindle, 1987, p. 160). Modifying traditional instruments or constructing different versions thereof or even new ones was also a way to obtain new sonorities. This was the case of composers like Ives, Alois Hába, Ivan Wyschnegradsky, Julián Carrillo, and Harry Partch who explored composition based in microtonal scales (Marco, 2002, pp. 274-276, 291-292).[16] Partch's *Adapted Guitar I* (ca. 1941) and *Adapted Guitar II* (1945), the former with removable frets, and the latter without frets, present cases of instrument modification (Schneider, 2014, pp. 178-183).[17] Other instruments that allowed for microtonality were some of those involving the use of electricity, with examples such as Lev Termen's *Theremin* which Varèse used initially in *Equatorial* (1932-34), opting later for Maurice Martenot's *Ondes musicales* (Marco, 2002, p. 293). Both instruments were introduced by the end of the 1920s (Holmes, 2008, pp. 19-27). Shortly after, in 1931, George Beauchamp and Paul Barth constructed the first electric guitar (Bronsac, 1975, p. 10). After *Equatorial*, Varèse's next step was the incorporation, in *Déserts* (1950-54), of recorded sounds – perhaps the greatest contrast of all.

The vast colour contrasts of the first half of the twentieth century gave place to music based on a few associated colours, due to influence of electroacoustic music. Therefore, "discovering and exploiting the timbre-contrast potentials" of solo instruments became the core of colour research (Brindle, 1987, p. 154). This "contributed to enriching the relation of the musician with its instrument, a fact of great importance for composers" (Von der Weid, 1997, p. 264).[18] It also gave rise to

[16] The term *microtonal* is used in this thesis for tones resulting from any kind of octave subdivision.

[17] Microtonal guitars have been introduced as early as 1829 (Schneider, 1985, p. 82; Westbrook, 2012, pp. 48-50).

[18] O.v.: Ce qui contribua à enrichir la relation, très importante pour le compositeur, entre le musicien et son instrument.

a great number of pieces for solo instruments, as for example Cage's *Solos* for Voice (1958/1960/1970), Gyorgy Ligeti's *Continuum* for harpsichord (1968), Karlheinz Stockhausen's *Zyklus* for percussion (1959) and Luciano Berio's *Sequenza* pieces. The latter, the first of which dates from 1958, exploit “every noise, tone, sound, and timbre that instruments can make” (Ross, 2007, p. 458). This was, however, carried out without attempting “to change the genetic inheritance of the instrument, nor … to use it 'against' its own nature”, stresses Berio (1998, pp. 9-10), who was “perhaps” motivated by “the slow and dignified transformation of instruments and of instrumental (and vocal) techniques across the centuries.” The influence of electroacoustic music is also felt in Helmut Lachenmann's music. For this composer, unconventional performance techniques such as those in his *Pression* for cello (1969) allow one to hear “under what conditions, with what materials, with what energies, and against what (mechanical) resistances each sound is produced”, giving thus rise to “instrumental musique concrète” (as quoted in Griffiths, 1995, p. 198). After the colour-research fever of the 60s and 70s had passed by, Lachenmann was one of the composers who continued in it, slowly finding himself among improvising performers, who turned to the research of the timbre space of each technique (Burtner, 2005, After Experimentalism, para. 3). The exploration (and exploitation) of unconventional performance techniques, often called *extended techniques*, gave and keeps giving rise to many books on the subject. The first of these books was possibly Salzedo’s (1921) *Modern Study of the Harp.* It was, however, after Bartolozzi's (1967) *New Sounds for Woodwind* that this kind of books started being regularly published.

2.1.3 Amplification of soft sounds

> The microphone is now accepted as a musical instrument since Mikrophonie I. … Discover the micro-world of the acoustic vibrations, amplify it and transform it electronically.
> Karlheinz Stockhausen[19]

Amplifying soft sounds was another means used to obtain new colours. This was often associated with the exploration of unconventional sound-sources or performance techniques. It was for the many of the new colours only perceivable very near the tam-tam that Stockhausen recurred to amplification in *Mikrophonie I* (1964). This piece presents a particular case, as the microphone ended up being used as an instrument, changing the colour of the captured sounds by picking them up from different directions and at different distances (Stockhausen, 1989, pp. 76-87). The microphone acts then “as both a smooth envelope shaper and filter at the

[19] In K. Stockhausen, *On Music*, p. 87.

same time" (Emmerson, 2007, p. 129). One of the first examples of the use of live amplification of soft sounds is,[20] however, *Cartridge Music* (1960) by Cage, whose wish to amplify this kind of sounds goes back to 1937: "Centers of experimental music must be established. In these centers the new materials, oscillators, turntables, generators, means for amplifying small sounds, film phonographs, etc., [will] be available for use" (Cage, 1961/2004, pp. 27-28).[21] Cage fulfilled his wish in 1952 in the tape piece *Williams Mix,* of which "small sounds requiring amplification to be heard with the others" is one of the six categories of the raw material (Cage,1960). In *Cartridge Music*, small objects are inserted in phonograph pick-ups, and contact microphones are applied to chairs, tables, etc. (Emmerson, 2007, pp. 127-128). A similar approach can be found in Hugh Davies' *Shozygs*, invented musical instruments which he started building in 1968, consisting of various found objects amplified by piezo-electric pick-ups and possibly inspired by Cage's piece and by Stockhausen's *Mikrophonie I*, the first performance of which he participated in (Palermo, 2012). In *Rainforest IV* (1973), David Tudor also used contact microphones on objects to pick-up their vibrating surfaces when activated by sounds played through transducers fastened to the objects (Collins, 2007, p. 46). In David Behrman's *Wave Train* (1966) the sound is picked-up by the exciter itself: loose guitar pickups (connected to guitar amps) on the strings of a grand piano give rise to "a loud mix of guitar-like feedback, amplified piano and percussive rattling" (Collins, p. 42). The amplified piano is also to be found in George Crumb's *Makrokosmos* (1972) where "inside-the-piano techniques using small chains on the strings, plucking the strings in different ways, and carefully damping them … [are] amplified, bringing the sound from inside the instrument out into the hall" (Burtner, 2005, Extended Techniques, para. 4). In *Black Angels* for "electric string quartet" (1970), Crumb (1990) used "unusual string effects" to enhance the "highly surrealistic effect" which the use of amplification was intended to produce, as for example, bowing the strings between the stopping finger and the nut.[22]

To amplify or not to amplify

Sounds can be naturally or unnaturally quiet. If a composer asks to be played

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[20] The amplification of soft sounds is named by Emmerson (2007) of *projection*: "Projection is the bringing to perceptual foreground or focus of relatively lower amplitude sounds (or constituent components of sounds)" (p. 127). It is also "the additional placing of sounds into space" (p. 129).

[21] Not taking electricity into account, the wish to amplify soft sounds goes back to as far as 1626 when Francis Bacon, in *New Atlantis,* describes "soundhouses where we practise and demonstrate all sounds and their generation. ... We represent small sounds as great and deep" (as quoted in Gibbs, 2007, p. 21).

soft a sound which would be possible to play much louder, it could be due to a specific timbre. In the music of Salvatore Sciarrino, the sound “retains the vestige of silence from where it stems and to where it returns, silence which itself is no other than an infinite swarming of microscopic sonorities” (Sciarrino as quoted in Von der Weid, 1997, p. 372).[23] As Sciarrino explains, he uses soft dynamics to carry out complex timbral transformations, given that, in such situation, the individual characteristics of the timbres are not perceived. The specific timbres of naturally quiet guitar sounds have been the reason for their use by some composers. In *Sette Studi* (1990), Maurizio Pisati (1990) explored “the often discussed audibility of the guitar … not as a problem of acoustic volume, but rather as a feature of the quality of sound elements, of the quality of their juxtaposition, of levels of audibility naturally differentiated” (Introduction). He therefore confronts conventional sounds with sounds from unconventional performance techniques:

> When the 'traditional' sound appears, it stands out from the myriad of 'other' sonorities as if on a differentiated acoustic level, and *represents a sound apart*, rare, the exception, emerging clearly from the more frequently used sonorities (stopping, glissandi, striking, harmonics, harmonics on "false" positions, etc.) which so often lack substance and resonance typical of conventional sounds. (Pisati, 1990, Introduction)

Exploring the “differences and nuances of sonorities” has also been the approach of Hans Ulrich Lehmann (1992, Introduction) in *etwas Klang von meiner Oberfläche* (1991), in order to emphasise the “intimate chamber-music character of the guitar.”[24] In *Nach Innen* (1997), Christoph Neidhöfer

> illuminates the subtle sonorous possibilities of the guitar … the listener's ear is turned to the finest sonorous nuances, often in the softest dynamic range, and resulting in the fact that the noises which result from the action constitute a significant part of the sound. (Neidhöfer, 1997, p. 8)[25]

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[22] This gives rise to mostly soft and *thin* sounds because the sound is only radiated by the string and by the neck of the instrument, whereas normal tones have the soundboard to amplify them (Schneider, 1985, p. 129). Crumb uses this effect when citing music, to produce the “viol-consort effect” (Crumb, 1990)

[23] O.v.: Le son, chez moi, garde la trace du silence d'où il provient et vers quoi il retourne, silence qui lui-même n'est qu'un grouillement infini de sonorités microscopiques.

[24] O.v.: klangliche Differenzierungen und Nuancierungen; kammermuskalisch-intimen Charakter der Gitarre.

[25] O.v.: Das Stuck beleuchtet die subtilen Klangmöglichkeiten der Gitarre, ... Das Ohr des Hörers wird auf die feinsten klanglichen Nuancen gelenkt, oft im Bereich zartester Dynamik und mit dem Resultat, dass die durch die Spielaktion entstehenden Nebengeräusche einen wesentlichen Bestandteil des Klanges bilden.

The intention of requesting non-amplified soft sounds could also be to capture the audience's attention, or close listening. The latter was the intention of Marc Sabat in *For Magister Zacharias* (2002/4) which

> requires that a piano mechanism be played by applying precisely controlled pressure to the keys, causing the dampers to lift away from the strings without the hammers striking. It was conceived as a private music which could only be perceived in close proximity to its source. When performed before a larger audience, the piano mechanism may be amplified, causing normally struck keys as well as sounds of the audience to be magnified within a context of noisy melodies. (Sabat & Sabat, 2004)

To capture the audience's attention was the intention of guitarist Andrés Segovia by refusing to use amplification. “Just imagine what kind of stage animal you needed to be with a classical guitar to hold the attention of the whole Royal Festival Hall with no amplification”, points out Karadaglić in regard to Segovia (as quoted in Cullingford, 2012, p. 24).[26] If the concert hall is large, the guitar "is not heard at its loveliest for most people in that hall" stresses Williams (as quoted in Simon, 2010). Moreover, room acoustics also plays a role – as Morris (Nonken & Morris, 2002) recalls, “anything using guitar requires” a “sympathetic acoustic” (p. 19). Therefore, even normal-level guitar sounds may be difficult to hear when the room is not favourable to the guitar. For Williams, the guitar should ideally

> not be played in a large hall if we want to experience the full range of its tone, because it doesn’t sound the same at a distance of 20 meters or more. This is because it’s a partly percussive instrument, and the percussive aspects carry more than its other dynamic and tonal qualities, so what we’re hearing is not really a true guitar sound. (Williams as quoted in Simon, 2010)

When the sounds can only be perceived in close proximity and are performed before a larger audience, in the absence of amplification the listener's attention might be captured, but the gesture of the musician is then what remains to most of the audience. This was experienced by Stockhausen, who stresses the need of amplification in such a situation:

> In Zyklus [1959], some percussionists now and then produce very delicate sounds—with their fingernails on cymbals, or with fingertips on drumheads. The audience sees gestures, but hears nothing. Hence it is exactly in such places that amplification is urgently needed, by which you approach the same

[26] Segovia's virtuosity was sometimes not enough: Tanenbaum (2003) recalls him having to “stop a concert to ask someone to refrain from coughing or rustling a program, insisting that large crowds should make an effort to hear him” (p. 185).

thing that the percussionist hears.

> The thing is not only to archive music, and to create new artworks from known sound-sources through a new recording technique, but also to so amplify and spatially project music that one is physically enveloped in it like the interpreter, and the space of the auditorium is pervaded by acoustical events to such an extent that on all sides it takes on an omni-directional character. (Stockhausen, 1996, p. 87)

Executing the gesture without actually producing the sound can be a compositional element, moreover an important one since it emphasises the gesture (that would produce the sound) showing its significance, stresses Saunders (2011).[27, 28] When sound is produced, its straightforward amplification may "add an element of acousmatic dislocation"; when the sound is not familiar and is further spatialised, it may give "the image of a performer conjuring up a soundscape 'maybe yet maybe not' related to the instrumental gesture *as seen*[, which] can be powerful in its ambiguity" stresses Emmerson (2007, p. 129). It is this kind of ambiguity – "a wide gesture of the hand and hardly no change in the resulting sounds" and vice-versa – that Roman Pfeifer searched for in *Die illegale Ausübung der Astronomie* (in Rebhahn, 2010). For him, the gestures "are as important as the sound itself. Despite acknowledging that the low-level sounds of the piece do not "leave the stage area" in the absence of amplification (in Rebhahn), he prefers "the non-amplified (=ppp) version" for not being satisfied with the amplified sound (R. Pfeifer, personal communication, November 16, 2011).

Composing for guitar and orchestra has always been a challenge in what loudness levels concerns. The guitar concertos of Stephen Goss "are designed to be played with amplification so that subtle resonant textures can be heard in an orchestral context in a big hall" (Traviss & Goss, 2013, p. 31). On the contrary, Christopher Sainsbury wrote his 2001 guitar concerto "so that the bi-tones[29] could be played with orchestra without amplification." Although this worked in all rehearsals, in concert he "used a little amplification after all" (C. Sainsbury, personal communication, March 13, 2011). Amplification was initially also not intended in

[27] An example of this situation can be found in the guitar quartet *Spuren* by Jens Joneleit (2011), in this case preceded by the gesture with sound. Choreographer Xavier Leroy's piece "Movements für Lachenmann", a performance based on Helmut Lachenmann's piece for two guitars "Salut Für Caudwell", presents a curious example, in which sound and gesture have been dissociated (Oh Mensch [2013] provides excerpts of a performance).

[28] Recent research results show that judgments about music performance are made "quickly and automatically on the basis of visual information" (Tsay, 2013, p. 14583).

[29] Low-level sounds resulting from the vibration of both sides of the string when this is hammered.

Giacinto Scelsi's *Aitsi* for amplified piano (1974). However, when recording material for a piano piece, Scelsi incidentally used a broken tape recorder. “The result was a distorted piano sound which he then passed on to his assistants. What is striking is that he ordered them to keep the distortion and find a way to integrate it in the composition” (ZKM, 2011). Although amplification is used for the distortion of the attack of the sounds, it generates a *sub-product*: when sounds are left to decay *al niente*, this is perceived to last longer.

2.1.4 The case of multiphonics

The term *multiphonics* is used to describe the simultaneous production of more than one tone exclusively by blowing, or on a single string. The term was probably coined by Brindle, albeit as an adjective, when translating Bartolozzi's (1967) *New Sounds for Woodwind.*[30] According to O'Loughlin (1968), this book contains the first systematic treatise on multiphonics. This author, having been criticized for calling woodwind multiphonics *Bartolozzi chords* (Singer, 1978), because this falsely implies that the technique was discovered by Bartolozzi, explained why he rejects Brindle's term as a noun:

> The term “multiphonic” is useful, perhaps, but it has a ghastly pedigree. It combines Greek and Latin roots in a careless and probably ignorant way (cf. the word “television”). “Polyphonic” is clearly the correct word, but it has another meaning too well established to avoid ambiguity. I, too, believe that Reginald Smith Brindle invented the word “multiphonic”, but at least he always used it adjectivally. What has gained wide currency in the USA, e.g. in Thomas Howell's The Avant-Garde Flute, is the use of the word “multiphonic” as a noun. A few Greek-derived words ending '-ic' are used as nouns (e.g. harmonic), but normally words ending '-ic' are adjectives. Some collective nouns ending 'ics' (acoustics, aesthetics, dynamics) are also in common use. There seems no compelling reason, however, to accept the hybrid “multiphonic” as a noun, even if it is just acceptable as an adjective. … So for the future, I will adopt Robert Dick's accurate and linguistically consistent phrase “multiple sonorities” (see Dick's The Other Flute, Oxford). (O'Loughlin, 1978)

Reviewing the second edition of Bartolozzi's book, O’Loughlin (1983) welcomes Brindle’s new noun-phrase for such sounds: “Professor Brindle’s new phrase 'sound amalgams' is an excellent replacement for 'chords'.” The technique started receiving

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[30] The book was first published in English. The original term in Italian may have been *suoni multipli*. Nowadays the term *multifonici* also exists.

renewed interest after the first edition of Bartolozzi's book, having attained considerable popularity. The first publication mentioning multiphonics on stringed instruments concerns the guitar and dates from 1983. Research on bowed-string multiphonics started, however, to first receive renewed interest. Before focusing on woodwind and bowed-string multiphonics, a brief mention of multiphonics on brass instruments and on the piano follows. Information on vocal multiphonics is supplied by Isherwood (2013, pp. 73-76) and by Edgerton (2004) and his suggested readings and references, a list which is extended by Tran's (2009) bibliography.

Multiphonics in brass instruments usually means the mixing of the voice with the played note. This gives rise to summation and difference tones, and has been known and practised on the horn since the 18th century, as Campbell (2001) explains in his New Grove entry on multiphonics (which is absent in the dictionary's first edition of 1980). Contrary to what Read (1993, p. 159) states, multiphonics in brasses is not limited to singing along playing. It is possible to produce multiple-pitched sounds “by altering the combination of lip setting, tension, and pressure known collectively as the embouchure”, as Campbell points out. He calls this technique “lip multiphonics”, and stresses that it is only possible on the trombone (Campbell, 2014, p. 5). Dempster (1979, pp. 9-10) calls it “split tone” and points out to another multiphonics technique which he calls “vowel harmonics” and which is related to changes in the oral cavity. Davidson (2005, p. 2), apart from citing Dempster, cites Schiaffini (1982, p. 20) and Sluchin (1995, pp. 13-14) as authors noting the possibility of producing split tones. The trombone is the only brass instrument that, according to Bartolozzi (1967, p. 36), has proved suitable for non-vocal multiphonics.

Research on piano multiphonics is quite recent, and the sources of information on the subject are scarce: only two are of the knowledge of the author.[31] In the oldest, Walter (2014) starts by proposing a mathematic model based on Fibonacci fractions and on “mutations” thereof (pp. 16-22). With this model, one can calculate “which sound is to expect at a certain position on the string, and, vice-versa, where on the string is a desired sound produced” (p. 16).[32] He then presents a chart of multiphonics locations, and discusses practical and technical aspects (pp. 22-26). This is followed by a section on multiphonics on bowed strings – his model

[31] A third source will be available in the near future: Yazdani "is currently conducting research on 'multiphonics on strings of piano'" (Arash Yazdani: Composer and Conductor, n.d., Bio, Composer) and announces a document, soon to be available, on the “Study of multiphonics, vibrations and acoustical behavior of strings of piano” (Writings).

[32] O.v.: Auf welchem Ort der Saite welcher Klang zu erwarten ist ... , und auch umgekehrt, wo der Ort für einen bestimmten gewünschten Mehrklang zu finden ist.

can also be used on these instruments, stresses Walter – and on the clarinet, and to how, in one of his pieces, he combined the sounds of multiphonics on these instruments with those of piano multiphonics (pp. 27-30). In the last part of the paper (pp. 30-39) he discusses "which compositional and aesthetic interconnections arise between the sounds of piano multiphonics and harmonic microtonal music" (p. 39),[33] noting the similarity between the structure of the former and that of difference-tone chords (p. 31).

Kubilay, Vesikkala, Pàmies-Vilà, Kuusi and Välimäki (2015) have compared the measurement of the vibration at a single point of a piano string in multiphonics by a conventional microphone with that by a high-speed line-scan camera. Their results show that the waveform obtained from the camera capture is more detailed than the microphone signal, allowing to determine the moment of release of the touching of the string – thereafter the string acts as an untouched string. Moreover, the measurement obtained by this novel method is free from external acoustic noise, including that from the instrument's radiation, capturing only the strongest partials of the string vibration (p. 8). This method does not capture, however, the movement of the vibrational modes with a node at or near the camera position (p. 7).

Woodwind multiphonics

> Of all the newer techniques applicable to the wind instruments, none figure more prominently in the scores of the avant-garde than multiphonics.
>
> Gardner Read[34]

The technique of woodwind multiphonics has been known since the beginning of the nineteenth century. The production on the flute of two-pitched sounds has been mentioned as early as 1802 by physicist Ernst Chladini, and achieved by flutists in Vienna and Paris around 1820. Among these are Jamme, who appears to have published around 1820 a "School for Harmonic, or Two-Part, Flute",[35] and Georg Bayr, who published after 1825 the first of four planned parts of a " School for Double Notes on the Flute" (Meylan, 1974b, pp. 102-103).[36] A few years after the publication of Bayr's method a 1837 concert review describes clarinetist Johann Gottlieb Kotte's special technique for playing two specific harmonic intervals of a 6th (Reissenberger & Hoeprich, 2014, p. 458). The unusual sounds were, however, considered by composers of that epoch as useless, as Meylan stresses (p.

[33] O.v.: Welche kompositorischen und ästetischen Querverbindungen sich zwischen Klaviermehrklängen und harmonischer mikrotonaler Musik allgemein ergeben.

[34] In G. Read, *Contemporary instrumental techniques*, p. 150.

[35] O.v.: Méthode de flûte harmonique ou à doubles parties.

[36] O.v.: Schule für Doppeltöne auf der Flöte.

103). In the twentieth century the sounds started being used possibly by jazz saxophonist John Coltrane. According to Moore (2014), Coltrane learned multiphonics from saxophonist John Glenn (p. 196) and recorded its sounds for the first time in 1957 (p. 190); in this same year, John Cage asked for "undertones" in *Solo for Clarinet* and for "intervals" in *Solo for Flute* (p. 190); and in 1958 written fingerings for sounds of multiphonics were provided by Franco Evangelisti in *Proporzioni* and by Luciano Berio in *Sequenza I* for flute (pp. 189-190). The latter piece's "double notes ... opened up the way for all the bedlam around 'multiphonic' sounds", recalls Berio for whom the sounds have a function more symbolic than practical: "they are a bit the sign of [his] desperate search for polyphony with history's most monodic instrument" (Dalmonte & Berio, 1981/1983, p. 132).[37] There was indeed much ado about the technique: in the beginning of the 1980s, "the interest in, and development of, multiphonics ha[d] been far more extensive than that of any other 'new' sound", recalls Post (1981, p.113). As with any unexplored territory, this was carried out by "a small group of adventurous performers" (Farmer, 1978, p. 48).

Benade (1974) provided the first explanation of the acoustics of woodwind multiphonics and included it two years later in his *Fundamentals of Musical Acoustics* (Benade, 1976). He recalls that his multiphonics research had been instigated by a letter from the early 1960's by a "music-loving engineer" questioning him about "certain multiple sounding tones" produced by Coltrane, since the latter refused divulging the methods he used (Benade, 1990, p. 559). Benade explains the term multiphonic based on our auditory perception:

> When we hear the conglomerate of partials making up a multiphonic sound, our hearing mechanism tends to pick from the collection sets of harmonically related or almost harmonically related components. Each of these sets is then heard as a tone of a more or less normal sort, having a pitch that is related in the normal way to the fundamental frequency of the set.
>
> … Our auditory habit of lumping a harmonically related set of partials into something that is perceived as a single tone explains why musicians give the name *multiphonic* to the sound we have been discussing. Each multiphonic, because it has sounds in it that are not harmonically related to each other, is perceived as being made up of a number of tones. (Benade,

[37] O.v.: Quant aux doubles notes (... qui ont ouvert la voie à tout ce chahut autour des sons "multiphoniques" ...), elles assurent ... une fonction plus symbolique que concrète: elles sont un peu le signe de ma recherche désesperée de la polyphonie, avec l'instrument le plus monodique de l'histoire.

1990, p. 567)

Shortly after Benade, Backus gave the same explanation for the acoustical phenomenon in reed instruments:

> Multiphonic tones ... are produced by the simultaneous vibration of the air column at two frequencies that are not harmonically related. One of these frequencies is generated by the lowest resonance of the air column; the other frequency is generated by a higher resonance such as the third or fourth. The reed maintains both these vibrations, oscillating at the lower frequency with the higher-frequency vibration superimposed. During part of the low-frequency cycle the reed aperture is partially or completely closed and can maintain the high-frequency vibration less well or not at all. Hence the high-frequency air column vibration is modulated to greater or lesser degree by the low-frequency vibration. As a result there are produced also two more air column vibrations (sidebands) whose frequencies are, respectively, the sum and the difference of the two original vibration frequencies. (Backus, 1978, p. 599)

This is the second of the three different mechanisms outlined by Bader and Hansen (2008, pp. 431-436) when proposing the third:

1. Overtones/undertones of the fingered pitch sound along with the fundamental. This occurs when a reed instrument is overblown/underblown with normal lip pressure.
2. Summation and difference tones arise as the result of the coupling of two vibrations. This occurs when complex sound-hole closing patterns are used (needing sometimes embouchure adjustments), or when inhomogeneity in the instrument geometry is created.
3. Two frequencies within each eigenfrequency pressure distribution arise, as this is two phased. This occurs when complex sound hole closing patterns are used.

A myriad of publications on woodwind multiphonics followed Bartolozzi's book. Barata (1988) compiled an annotated bibliography “primarily for use by composers and performers” containing publications up to 1985 “which directly explain the production, use, or notation of multiphonics” (p. 246).[38] Castellengo (1982) pursued

[38] Barata does not reference, at least, the following publications: P.-Y. Artaud and G. Geay, *Present day flutes*; G. Braun, *Neue Klangwelt auf der Blockflöte*; R. L. Caravan, *Preliminary exercises & etudes* ; R. Dick, *Tone developmemt through extended* techniques; G. Farmer, *Multiphonics and other contemporary clarinet techniques*; G. Farmer, *Multiphonic trills and tremolos for clarinet*; M. Gümbel, *Neue Spieltechniken in der Querflöten-Musik*; D. Kientzy, *Les sons multiples au saxophones*; M. Kientzy, *Les sons multiples aux flûtes à bec*; R. Meylan, *La flûte*; S. Penazzi, *Metodo per fagotto*; H. Riedelbauch, Bassonographie.

to fill the gaps in the books of this kind by providing musicians with accessible information on the acoustics of wind-instrument multiphonics and on how it relates with perception. After a theoretical introduction, she presents the results of the spectral and auditive analysis of selected sounds on the flute, the oboe, the bassoon, the bass clarinet and the trombone. After 1985, new works "expanding the field to instruments outside the standard woodwind family" were published, filling this gap pointed out by Barata (1988, p. 248);[39] woodwind multiphonics continued to be the subject of doctoral theses (Bergeron, 1989; Davis, 1997; Haddad, 2006; Moore, 2014; Phelps, 1998; Shiiung, 2008); and online publications made the subject more accessible and its presentation more flexible, as exemplified by the website by Del Grazia (ca. 2003). Some webpages are, however, still incomplete: Redgate (n.d.[40]) promises "a great deal of information … including an enormous list of fingerings, some discussion of the problems with multiphonics etc.", whereas Richards' (2004) "interactive, searchable database of multiphonic fingerings" is not to be found (Multiphonic Chart).

In many publications the analysis of the sounds was, or appears to have been, carried out aurally (Arthaud, 1995; Bok, 2011; Bok & Wendel, 1989; Chenna & Salmi, 1994; Dick 1986; Gallois, 2009; Gross, 1998; Kientzy, 1990, 1993; Koizumi 1996; Leonard, 1989; Levine & Mitropoulos-Bott, 2002, 2004; Londeix, 1989; O'Kelly, 1990; Rechberger, 1987, 1991; Rehfeldt, 1994; Van Cleeve, 2004; Weiss & Netti, 2010). Weiss and Netti's justification therefor is the following:

> The 'sense' of the sound should, of course, always derive from musical listening. Our own hearing has been cultivated over years of instrumental and compositional practice within a particular sound world and what we have heard, revised repeatedly, is what we trust. (Weiss & Netti, 2010, p. 58)

Spectral analyses of the sounds were carried out by Archbold and Redgate (n.d.a, n.d.b), Gottfried (n.d.), Richards (2004), Riedebauch (1988), Riera, Proscia and Eguia (2014), Ross (2014), Sampson (2014) and Sève (1998), as well as by Krassnitzer (2002), Sparnay (2012), Veale and Mahnkopf (1994) and Watts (2015) who provide a CD with audio examples. The books by Gallois (2009) and Levine and Mitropoulos-Bott (2004) are also accompanied by a CD with audio examples, whereas the audio examples of Weiss and Netti (2010) can be found online. The latter three books, as well as that by Veale and Mahnkopf are bilingual or trilingual

[39] Literature on multiphonics on the saxophone and flute families existed but Barata does not reference them (Artaud and Geay 1980; Kientzy 1982).

[40] This page contains a link to a co-authored publication on multiphonics notation (Redgate and Archbold n.d.).

editions (in English and German, or English, German, and French).

Some authors point out problems which are specific of an instrument, whereas the problems pointed out by others are extensible to other instruments. The former case is that of Pino (1998), who finds that the sounds are less successful on the clarinet than on other instruments, due to the impossibility of the instrument of playing even-numbered partials (p. 71). In regard to more general problems, Riera, Proscia, and Eguia (2014) note that "fingerings are usually not efficient in the same way for different saxophonists and saxophones" (p. 203); Sampson (2014) stresses that "it is unreasonable to expect one multiphonic fingering, tested on one bassoon, to work on all bassoons" (p. 15); and Van Cleeve (2004) points out that "the oboe is a complex system with [many] variables … [which] present a challenge in the standardization of reliable fingerings that will work across the range of oboe types, reed types, and players" (p. 32). Therefore, Van Cleve, who provides with her book a CD with audio examples, tested her fingerings with "five different oboists who had different oboe types, reed styles, and training. To be included in the list, each fingering needed to work reliably for four out of five of the oboists" (Van Cleeve, 2004, p. 32). Richards (2004) also claims his *Multiphonic Chart* to have "been checked by numerous players for accuracy"; and Gottfried (n.d., p. 3) not only recurred to more than one instrument but also to several takes. The three saxophones of Gottfried's experiment were, however, only played by one saxophonist. This could be explained by the fact that one of the goals of the experiment was to compare saxophones of different manufacturers. Ewell (2011) and Sampson (2014) tested fingerings from various resources with respectively two and twelve bassoonists and their respective instruments.

The research by Sampson (2014) is possibly the most encompassing, given that testing involved a significant number of players and the use of spectral analysis. She tested 369 fingerings which were collected and compared from six resources. The twelve bassoonists were asked to report on the following factors: successful production of a sound of multiphonics, dynamic range, and prevalence of response issues. She then grouped the sounds according those factors, eliminated the fingerings which less successfully produced multiple-pitched sounds, and organised the groups into categories. The sounds produced by the selected fingerings were then recorded with mini condenser microphones placed at the bell and over the left-hand tone holes of the instruments. This step also involved twelve bassoonists, some of which had participated in the previous step. The mixing of the tracks was then spectrally analysed. Sampson compared then the analyses of the sounds by the different players, in order to select the pitch content of the sounds resulting from each fingering, for the notation of which she proposes four styles. Sampson hopes that her work “eliminates some of the concern regarding some fidelity when these multiphonics are performed by additional bassoonists", helping then composers “to make informed decisions about specific multiphonics, understand their response issues, and more accurately predict the sonic result of each" (p. xvi).

Most authors have categorised the sounds of multiphonics. Their criterion is usually related to a general information descriptor related to sound production (e.g. kind of fingering: conventional or unusual) or to the sounds (e.g. stability: stable or pulsating). Once the individual sounds are charted, they are then ordered according to a specific information descriptor (e.g. lowest/highest resulting pitch in ascending order). As with the notated resulting pitches for each fingering, the categorisations of the sounds stem usually only from the perception of its authors. This is, however, not the case of the categorisation by Proscia (2009a, 2009b, 2011), which was confirmed by testing with five subjects unaware of it (Proscia, Riera and Eguia, 2011, 2012; Riera, Proscia, and Eguia, 2014).

Bowed-string multiphonics

> Multiphonics could become as important to the development of new string technique as they have been to woodwind but are currently barely represented in handbooks of instrumental technique for string instruments.
>
> Ellen Fallowfield[41]

On bowed strings the technique works best on the cello and on the double bass, and most publications dealing with the subject concern these two instruments. Guettler and Thelin (2012) define multiphonics in string instruments as “mainly a filtering technique, where the potential energy of certain partials [sic overtones] of an (in most cases) open-string fundamental is restrained by a left-hand finger pad lightly touching the string” (p. 766). These authors have identified in the (double-bass) bowed-string behaviour

> two additional signal loops, one on each side of the finger, which, through the repeating slip pattern, get phase locked to the full loop of the fundamental. Within the nominal period, however, the slip pulses will not be uniform like they are during the production of a normal “harmonic” or “flageolet”, but may vary considerably in shape, size, and timing. (Guettler & Thelin, 2012, p. 766)

The filtering (to which the bow also contributes) defines “the conditions for the different frequencies to develop and survive”, determining the characteristics of the slip pulses during a nominal (open-string) period (Guettler & Thelin, 2012, p. 770).

[41] In E. Fallowfield, *Cello map*, p. 20.

There are two filtering mechanisms, depending on whether the finger (class one), or the bow (class two), lie closest to the bridge (Guettler & Thelin, 2012, p. 768). In the spectra of class-one sounds the partials are concentrated in the vicinity of a louder partial, and in those of class-two sounds they are spread-out (Guettler & Thelin, 2012, pp. 770-771). The stability of the sounds is related to bow pressure and speed.[42] Class-one sounds are more stable but, nevertheless, “bowing must be performed with great control and consistency” (Guettler & Thelin, 2010, p. 4). The instability of bowed-string multiphonics is also stressed by Fallowfield and Resch (n.d.: Multiphonics and other multiple sounds): “a balance between flexibility of colour/loudness and reliability of multiphonics is difficult to achieve”; and by double-bassist Uli Fussenegger, who finds more interesting to use the sounds as elements of a texture than per se:

> The technical flexibility with multiphonics is limited – you cannot play a *sforzatissimo* nor large *crescendi* or *diminuendi* because then the sounds are lost. These need such a special treatment that the musical approach for them – what you can do with them – becomes incredibly limited. That is not bad but I find it a very difficult challenge to compose well using them. It is like composing a good piece for a woodblock ... it needs the tightest discipline. (U. Fussenegger, personal communication, Feb. 8, 2011)[43]

Bowed-string multiphonics started being researched in the 1980s. Robert (1995) claims to have made a first communication at IRCAM in collaboration with Rădulescu in 1983, and to have carried out research in collaboration with that institute in 1985 (p. 22). The first publication mentioning the subject is possibly the revised edition of a 1974 handbook for double bass by Turetzky (1989, pp. 138-139). Knowing “of no music employing string multiphonics”, he gives only one example to “demonstrate the principle”, because the subject “is entirely new ground, it remains for composers and performers to build the usable technique and notation” (Turetzky, 1989, p. 138). Two years after Turetzky's book, in a peculiar handbook for cello, Bach (1991) calls multiphonics a “coincidence of two or more nH [partial tones] on the same string.” He devotes a single page to the technique (p. 32), providing three

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[42] *Bow pressure* is the usual term by musicians for *bow force* (Guettler 2010, 287).

[43] O.v.: Die technische Flexibilität mit *Multiphonics* kommt natürlich über ein gewisses Level nicht hinaus – du kannst kein *sforzatissimo* spielen, du kannst kein ganz starken *crescendi* und *diminuendi* spielen, weil dann sind sie einfach weg, sie brauchen so eine spezielle Behandlung. Das heißt der musikalische *approach* damit ist wansinnig limitiert, was du damit machen kannst. Es ist nicht schlecht aber finde ich eine sehr schwere Herausforderung, gut zu komponieren. Das ist wie schwer ist ein Stück für Woodblock zu schreiben, was gut ist. (...) Es ist die Königsdisziplin.

examples, and reproducing an excerpt from the score of *One8* (1991), a piece dedicated to himself by John Cage.[44] Bach mentions the technique producing “a unique sound characterized in particular by strong differential tones” (p. 32). In the light of the above-quoted definition by Guettler and Thelin, the difference tones arise, in fact, from non-damped-out vibrational modes. Difference tones are also mentioned by Dresser (2000, 2009, 2010), who addresses essentially practical advice on the production of double bass multiphonics. It is however worth noting that he distinguishes between two kinds of sounds, one “chord-like” and the other involving “an oscillation between its components” (Dresser, 2009, p. 73). These types correspond to Guettler and Thelin's (2012) classes two and one, respectively.

The first systematisation of bowed-string multiphonics is possibly that by Robert (1995, pp. 21-32). This author, who supplies audio examples with his book, stresses that “the mastery of pressure, speed and precision in placing the bow, of great importance in playing harmonics, are essential to the realisation of multiphonic sounds … The realisation of certain sounds demands a specific left-hand finger pressure technique” (Robert, 1995, p. 21). Robert points out the possibility of making a transition from a sound of multiphonics to a sound of harmonics, or vice-versa, by changing the touch pressure or the bowing conditions (p. 21), and touches on the subjects of sound perception and artificial multiphonics (p. 22). He charts only the “more stable aggregates” (p.22) providing the results of “electronic” and “acoustic” analyses (pp. 26-30). Regarding the differences between the results from the two kinds of analyses, Robert adverts that one should not be surprised, as with the acoustic analyses his aim was to transcribe what is heard in “simple, everyday listening” (p. 22). In the results of the acoustic analyses he distinguishes between “precise notes of the effect” and “imprecise notes which color the effect”, and marks the sounds with “low reliability” (p. 30). Robert appears to have been the only author dealing with bowed-string multiphonics who used spectral analysis.

Bowing conditions were only systematised in this century. Liebman (2001, 2010), who deals with cello and double bass multiphonics,[45] uses four descriptors for bowing: placement, pressure, speed, and direction.[46] For example, he considers seven bow placements between the end of the fingerboard and the bridge, all with the length of the bow width (Liebman, 2010, pp. 29-30). After discussing the

[44] This is possibly the first piece requesting bowed-string multiphonics.

[45] According to Thelin (2011, p. 4), a 2001 article on double bass multiphonics remains unpublished.

[46] “Bowing angles other than perpendicular to the string promote multiphonics” (Dresser, 2009, p. 75)

production of the sounds, Liebman (2010) briefly mentions artificial multiphonics, and points out to the possibility of transitions between harmonics and multiphonics, and vice-versa (pp. 34-35). He then goes through techniques which can be used to vary the sounds' colour (Liebman, 2010, pp. 35-36), and supplies charts with stable sounds for both instruments. The chart for the double-bass is much more extensive but, whereas “the diatonic frame has been left intact in the case of [the] double bass, ... quarter-tones were used in the cello table” (Liebman, 2010, p. 26). Liebman (2010) considers the exact results of spectral analyses “not compulsory” for the practical use of the technique, “due to the great variety of instruments as well as the fluidity of resulting sounds with even slight bow shifts” (p. 27). Instead, he used “a traditional, aural analysis”, notating only “clearly audible” components (Liebman, 2010, p. 27). He stresses though that

> seeing the notation of the chord is necessary only when a composer is looking for nuances of this technique. It is relevant in those cases when a chord is perceived by the composer as not just a sonorous entity, but as a full-blown chord, with its melodic and harmonic features. (Liebman, 2010, p. 27)

The latest publication by Liebman (2010) is accompanied by a score and a CD with audio examples.

There was an increase in research of bowed-string multiphonics in the present decade. In a cello-multiphonics blog, after outlining how to play the technique, Marino (2010) suggests a notation for the action, which includes three approximate locations for bowing ("~ sul pont", "~ sul tasto" and "~ ext. sul tasto"). She provides examples for each string organised by decreasing touch-location pitch. The resulting sound of each example can be heard and viewed in the video clips supplied. Marino suggests listening to the examples through headphones, as the sounds are sometimes “quite subtle in their differences” (Multiphonic Introduction). In an article on the cello's high harmonics and the Farey sequence, Devoto (2011) discusses the production of multiphonics, provides examples, and reproduces score excerpts (pp. 68-73). The last section of the article is dedicated to artificial high-harmonics and artificial multiphonics (Devoto, 2011, pp. 74-76). In his examples, Devoto notates action and result, indicating the precise bow placement in multiphonics in terms of string-node location. For score usage, however, Devoto suggests approximative indications: “poco sul pont., molto sul pont., poco sul tasto, etc” (p. 72), contrary to Guettler and Thelin (2010), who find that situating node locations in those zones of the string should not be a problem for “the (accomplished) player” (p. 3).

Bowed-string multiphonics has also been the subject of academic theses. The approach by Thelin (2011) departs form the spectral results he obtained with Guettler, and from Liebman's (2010) approach. Thelin stresses that he has kept “strictly to the research of clearly defined and reproducible multiphonic sounds. The vast arrays of sounds that can be created with prepared instruments or amplification are not subject to this scrutiny” (p. 1). His main aim was to illustrate double bass multiphonics through examples from musical compositions, for which he includes score-excerpt reproductions, and discusses them. The notation he suggests when discussing sound production does not include the result and this is not provided in the charts. Thelin deals with artificial and pizzicato multiphonics stressing that the latter should always be excited “energetically close to the bridge” (p. 17). Like Liebman, he also describes effects which can be used to vary the colour of the sounds. Thelin systematises the touch location, the bow placement, pressure and speed, the colour of the sounds and their “playability”. The latter, he acknowledges to be “an intimately personal matter” which depends on “the instrument set-up, choice of strings, and the performers own style of playing” (Thelin, 2011, p. 43). Thelin finds it “difficult to define any general behaviour of bow resistance”, because, contrary to conventional playing, in which an increase in bow pressure and speed leads to a greater volume, in multiphonics, although the volume of sound is usually proportional to bow speed, “the pressure is not always in direct correlation to the dynamics”; each sound requires then “a specific combination of pressure and speed which can only be learned by experience” (p. 10). The charts Thelin supplies show only the “most usable” locations (p. 43).

For her thesis, Fallowfield (2012) limited the investigation to sounds containing partials with mode number lying in the range of 2 to 13 (p. 12). She started by analysing the influence of bow speed, pressure and placement on the colour of the sounds, and then associated three touch zones and respective bowing conditions to three colour categories (Fallowfield, 2012, pp. 13-14, 17). In accordance with the results of Guettler and Thelin, Fallowfield stresses that, when the finger lies closest to the bridge than the bow, the sounds are more stable (p. 15). Pizzicato and artificial multiphonics are touched upon by Fallowfield who suggests the former to be played with nail (p. 19). Fallowfield acknowledges that the notation she suggests, which works only in combination with the provided fingerboard sketch, is not usable in a score but “is practical, exact and in a format that would suit a legend or exercise book” (p. 11). This notation has been improved and the location on the string is now, for one of the categories, provided in conventional notation in a detailed chart; additionally, video demonstrations are supplied (Fallowfield & Resch, n.d.).

There is only one source to the author's knowledge dealing explicitly with violin multiphonics. Here, Strange and Strange (2001) discuss the sound-production methods of other authors, propose a notation, and finish by stressing the importance of bow pressure and speed (pp. 132-134). In their bilingual book, which includes a DVD with video examples, Arditti and Platz (2013, pp. 69-70) give practical advice on playing on the violin two simultaneous pitches on one string, using “base notes with harmonic overtones.” This consists in playing harmonics with increased bow pressure on the open string or on the quasi-stopped string. The former case is what Fallowfield and Resch (n.d., Other multiple sounds) call “overpressure harmonics”: when the bow pressure is increased, the open-string fundamental is incorporated in the sound. This technique can be categorised as multiphonics according to the definition of Guettler and Thelin (2012, p. 766), because all components belong to the same series of harmonics. This is, however, not true for the sounds that incorporate the sound of the quasi-stopped string.

2.2 Colour Research on the Guitar

> Formerly the oboe was pastoral and the guitar was Spanish. Now it is used for its timbre which is very beautiful, very hot (cf the Marteau sans Maître). Nevertheless, it is conceived for the tonal music and it suffers from it.
> Tristan Murail[47]

> The guitar is a "knowing" or "knowledgeable" instrument, with many limitations but also many unexplored spaces and depths within those limits.
> Hans Werner Henze[48]

The guitar lags behind many instruments in colour research. This kind of research is usually carried out on the guitar by composers who do not play the instrument. Yet most music for guitar stems from guitarist-composers, and the “trend is growing, as many young players are composing as well”, stresses Tanenbaum (2003, p. 201). Two recent *Soundboard* issues devoted respectively to “Composing for Guitar” (Soundboard, 2013) and “New Music” (Soundboard, 2014) confirm this: all featured composers but one are also guitarists. This situation is analysed in sections 2.2.1 to 2.2.4. Section 2.2.5 discusses ways to promote colour research on the guitar.

2.2.1 Guitarist-composers

Composing for its own instrument may be limiting. One is enclosed in the

[47] In R. Andia, & T. Murail, Interview of Tristan Murail, 7th answer.

[48] As quoted in D. Tanenbaum, The classical guitar in the twentieth century, p. 194.

idiom of the instrument and it is difficult to go beyond it. Gilardino (1994) sees the insistence of guitarist-composer Miquel Llobet with Manuel de Falla to write for guitar as "a gesture of civism and hope", in which there was also perhaps "the reckoning of the boundary reached by the research of an instrumentalist who composes from the inside of an idiom" (p. 5).[49] A boundary which guitarist-composer Stephen Goss is always trying to overcome:

> If you're a composer and a guitarist, then you tend to know the dark secrets of the instrument, but there is a danger that you depend too much on familiar formulas and pre-conceived ideas of the instrument's boundaries. ... I'm always trying to escape default responses to musical stimuli—the war against cliché, as Martin Amis put it. I think composers have to keep finding new and interesting ways of writing for the guitar in the light of an already extensive repertoire. (Traviss & Goss, 2013, p. 30)

This attitude is, however, an exception, for which guitarist Magnus Andersson turned away from the circle of guitarist-composers:

> The quantitative progress [in repertoire] was not, however, always accompanied by a corresponding qualitative improvement. Instead, it more likely confirmed the ancient prejudice of an instrument so tributary of its idiomatic a priori that any compositional attempt outside the specialised circle of guitarists and guitarist-composers was impossible. I then searched for music that was not influenced by the established guitar aesthetic. A music that would distance itself from the narcissistic virtuosity, without having to renounce its sensuality. (Andersson, 1988, p. 128)[50]

Some non-guitarist composers feel also disappointed with the conservative approach to guitar composition by guitarist-composers. Composer Toru Takemitsu, who, "of all the instruments he wrote for, ... loved the guitar the most", felt frustrated "with guitarist-composers who were afraid to either leave tonality or fully embrace it", recalls guitarist David Tanenbaum (2003, p. 193), who stresses that much of the music by these composers "blurs the formerly held lines of classical and pop" (p. 201). This may be explained by the fact that guitarists and, consequently, guitar-

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[49] O.v.: C'è forse, in questo gesto di civiltà e di speranza, anche l'amissione del limite in cui fatalmente s'imbate la ricerca dello strumentista che compone dall'interno di un idioma.

[50] O.v.: Le progrès quantitatif, toutefois, ne s'accompagnait pas toujours d'une amélioration qualitative correspondante, mais tendait plutôt à confirmer le anciens préjugés à l'encontre d'un instrument si tributaire de ses a priori idomatiques qu'il rendait impossible toute tentative de composition, en dehors du cercle spécialisé des guitaristes et des compositeurs pour la guitare. Une musique qui se distanciât de la virtuosité narcissique, sans pour autant renier sa sensualité.

composers are usually too imbedded in the predominant guitar aesthetic, which is a conservative aesthetic, and a legacy of guitarist Andrés Segovia.

2.2.2 The legacy of Segovia

> One reprehensible drawback to the development of the guitar as an instrument with a classical background and technique has been the narrow-minded, reactionary and, in many cases, unmusical attitude of its most "pure" advocates.
> John Williams[51]

Segovia was one of the main actors in the promotion of the guitar in the twentieth century. In his own words, he raised the instrument “to the loftiest levels of the musical world” (Segovia as quoted in Tanenbaum, 2003, p. 184). There was, however, a price to pay for this:

> He so thoroughly dominated the scene that his name became synonymous with the term "classical guitar". Its audience was conditioned to the Segovia style. But if his rise to fame was the *sine qua non* for a guitar renaissance, his success playing king of the mountain had negative, even suffocating consequences. In Segovia's wake, any guitarist seeking an audience had to conform to his conservative repertoire, if not to his approach to interpretation. And a composition for guitar had little chance of success without him performing it. (Hodel, 1999, p. 14)

Although Segovia played a significant role in enlarging the classical guitar repertoire, he did little to enrich it. Instead, he rather “consolidated and extended a conservative viewpoint”, stresses Hodel (2000, p. 8). Segovia had “vowed to rescue the guitar from its small-minded enthusiasts by eventually, when the time was ripe, approaching leading composers and asking them to write for guitar” (Wade, 1980, p. 151). However, as Tanenbaum (2003, pp. 184-185) points out, Segovia never paid for a single piece, and was “adamant in his dislike for the modernist stream of composition”, playing only “music he believed in” (he turned down an offer of Schoenberg to write for him). This resulted in a lack of *great composers* in his original repertoire. Nevertheless, as Segovia never promoted or played music by a living guitarist-composer (Tanenbaum, 2003, p. 185), that repertoire consisted exclusively of pieces by non-guitarist composers.[52] This was for Miteran (1997, p. 235) Segovia's greatest achievement, because, as shall be discussed below, the difficulty in writing for guitar usually turns away non-guitarist composers. The musical lines of the pieces written for Segovia are, however, free from the typical problems

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[51] J. Williams as quoted in G. Wade, *A concise history of classic guitar*, p. 166

[52] Some composers like Villa-Lobos were, however, well acquainted with the instrument.

arising from the fact of a composer hardly knowing the instrument. According to Gilardino (1994, p. 6), this is thanks to Segovia's “revisions”, which he considers questionable when compared with the original scores. Therefore and having present that Segovia ignored Martin's *Quatre Pièces Brèves*, which were written for him (Tanenbaum, 2003, p. 190), any compositional attempt outside Segovia's aesthetic may have been suppressed. This could have contributed to give guitarists a reputation that could also explain the “missed out repertoire”[53] of the first half of the twentieth century: *great composers* could not see in guitarists *great musicians,* who could understand their artistic demands and with whom they could feel in equal situation (Moser, 1983, p. 394). The lack of interest by those composers was not then on the guitar but in writing for guitarists.

2.2.3 The effort of Bream

Guitarist Julian Bream tried to establish a bridge between Segovia's conservatism and a more adventurous path. In his recital format of that time, Bream "carefully excluded extreme avant-gardism though emphasising the contemporary. In this he continued the custom of Segovia and earlier guitarists but extended the essential framework to the point where there could be no return to former limitations" (Wade, 2001, p. 158). One of the first pieces requested by Bream was Britten's *Nocturnal* (1963). Its premiere in 1964 marks for Wade “the beginning of the end of Segovia's domination over the twentieth century repertoire” (Wade as quoted in Tanenbaum, 2003, p. 192). For Tanenbaum (2003), the collaboration of Bream with composers “directly helped create what may be the greatest legacy of music that any guitarist has left, far more diverse and adventurous than what was written for Segovia” (p. 191). According to Morris, Henze's *Royal Winter Music I* (1976) “exists as a result of Julian Bream's request for a work similar in proportion and importance for the guitar as the *Hammerklavier* of Beethoven is to the pianoforte” (Nonken & Morris, 2002, p. 14). To aid non-guitarist composers, since these do not have “a clue” on how to write for guitar, Bream wrote a paper in 1957, hoping to "encourage composers to create a literature for an instrument that has been unduly neglected” (Bream, 1957/2003, p.1, 8).[54] Possibly aware that this paper is quite brief and “very much of its period” (Bream, 1957/2003, p. 1), the retired Bream commissioned from Leathwood a manual to share with the composers he commissioned to write pieces

[53] O.v.: verpaßte Repertoire.

[54] For Carfoot (2006), the “neglected-guitar” ideology was one of “a series of constructed ideologies around the instrument” upon which was based, or actively produced by, “Segovia's 'infamous' invention of the modern classical guitar tradition” (p. 36).

to be performed by other guitarists (J. Leathwood, personal communication, March 16, 2013). Apart from Leathwood (2010), other authors have also explicitly taken up the task of elucidating non-guitarist composers on writing for guitar (Andia, 1983; Gilardino, 1994, 1996, 1999; Godfrey, 2013; Kachian, 2006; Lunn, 2010; Ulloa, 2001).

Bream prepared the ground for a change, but this did not happen. If the guitar is present in the works of *great composers* this is usually in chamber music, and is the result of “opportunity work”, as “no noteworthy composer has shown renewed and sustained interest in the guitar” (Pfäffgen, 1988, p. 202).[55] This should be also related to the fact that, as Schneider (2015, p. x) stresses, single lines of music in an ensemble setting are “much easier to negotiate than the full contrapuntual textures demanded by the solo repertoire.” Therefore, “the guitar's repertoire consists of main works of irrelevant composers and secondary works of relevant composers” (Grün as quoted in Pfäffgen, 1988, p. 190).[56] In fact, many of the main works for guitar are by guitarist-composers whose works without guitar receive little attention. At the turn of this century, Goss (2000), “noting an increase in the number of performances of new works composed by guitarists” (section 3, last para.), asked:

> Is this because the idiomatic comfort and familiarity, and therefore ease of execution, of these pieces is seducing guitarists? Or is it simply the case that the guitar world is becoming increasingly ghettoised – guitarists travelling the world, playing music written by guitarists to audiences made up of guitarists? (section 3, last para.)

Both reasons are valid: "We still do not take enough chances ... and there can be a dulling sameness to our efforts", stresses Tanenbaum (2003, p. 205), whereas Gilardino points out that:

> Guitarists who filter the repertoire between composers and listeners are too naive and lazy, and they ignore the majority of the repertoire accumulated in this century for their instrument. Their choices are influenced mainly by fashions and by a desperate search of pieces easy to be listened and appreciated by everybody. There are exceptions of course, but they are too few: in a guitar recital nowadays it is common to listen to pieces whose quality is so poor that in no other musical event apart [from] a guitar concert they could be offered. (New Milllennium & Gilardino, n.d., answer 7)

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[55] O.v.: Gelegenheitsarbeit; Kein nennenswerter Komponist hat sich wiederholt und nachhaltig für das Instrument interessiert.

[56] O.v.: Das Repertoire der Gitarre bestehe aus Hauptwerken unbedeutender und Nebenwerken bedeutender Komponisten.

Gilardino (1973, p. 9) blames pedagogy for promoting this kind of attitude which, as Andia points out, leads to technical limitations:

> In general, the composers of the 20th century have written for the guitar with the intention of trying to find a compromise between their musical ideas and the arsenal of possible techniques that the performer could put at their disposal. This ensemble of means was evidently limited by the routine and playing habits of guitarists and a direct function of the classical or modern repertoire they practised. In the best case, the composer pushed this technique to the limits, but it was not generally a question of a change of nature or radical renewal. (Andia, 1984/n.d., A New Way, para. 2)

This attitude leads to frustration in composers, as expressed by Murail:

> It is especially necessary that the traditional guitarists evolve. I would like that they can control these new techniques ... and add them to the traditional ones. It is for all the instruments that the evolution is currently done in the direction of the timbre. See the winds where research led to multiphonic possibilities and complex timbres (Andia & Murail, 1984/n.d., answer 7).

2.2.4 Non-guitarist composers

When non-guitarist composers write for guitarists, these are usually adventurous guitarists. These guitarists prefer, in fact, to work with non-guitarist composers, because their music is not as idiomatic and conservative as that of guitarist-composers. Non-guitarist composers have often “to reach further to imagine sound on the guitar” points out Tanenbaum (2003, p. 202), who, by working with these composers, becomes “much more involved in the creation of the music and its realization on the instrument” (p. 202). Similarly, guitarist-composer Angelo Gilardino (1973) finds that non-guitarist composers, being more distant from the instrument, are in a better position to discover possibilities not imaginable by guitarists (p. 9). Guitarist Jonathan Leathwood (2010, p. vi), acknowledging that one or other “texture or type of sonority might be worth exploring more than it has been”, is also of the opinion that, “by reimagining the guitar’s sonorities and idioms, these [non-guitarist] composers have profoundly influenced the development of guitar technique and musicianship” and have composed the “most significant modern guitar works.”[57] As a reason for this state of affairs, Ribeiro (2012) , in turn, to the fact that many non-guitarist composers “write almost exclusively chamber music and/or orchestral music, because they come from a tradition with a great variety of timbre (colours).

[57] Improvised-music performers generate new techniques but their findings hardly reach the paper.

Many have searched for – and developed – means to obtain those same characteristics with the solo guitar” (p. 3).[58] Colour research on the guitar is hence better achieved by non-guitarist composers. There is, however, little compositional output for guitar by these composers, because they tend to avoid the guitar or prefer its electric counterpart. The reasons therefor are presented below.

Folk instrument

By the end the nineteenth century, the guitar was only present in music as evoked element. Composers “used the guitar as a model to try a stylisation of the 'Spanish language'” but left it out of the stage (De Persia, 1996, pp. 27-28).[59] In *El sombrero de tres picos* (1919), for example, Falla's intention was “to evoke by means of the instrumentation in particular passages, certain guitaristic values” (Falla as quoted in Wade, 1980, p. 156). This is related to the fact that, as Falla and as Hodel explain, the guitar was not suitable for the Romanticism aesthetic:

> Romantic times were precisely those in which the guitar was at its worst; and then, of course, it spread all over Europe. It was made to play the sort of music that other instruments played, but it was not really suitable for nineteenth-century music, and so it dropped out. (Falla as quoted by Trend in Turnbull, 1974, p. 110)
>
> The second half of the [nineteenth] century, dominated by the gigantism of Wagner, saw the instrument's decline to an anachronism and novelty. It simply could not speak the language of ultra-chromaticism and titanic energy. By the time Richard Strauss and Gustav Mahler brought romanticism to its culmination, the guitar was totally irrelevant to the central thrust of Western Art Music. (Hodel, 1999, p. 9)

Moreover, the “orchestral scores imitated the flamenco guitar. To transfer such dances to the classical guitar would become a redundant art after a while” – the orchestra was therefore more convenient “to convey the dimensions of Spanish culture” (Wade, 1980, p. 161).

The absence of the guitar on stage can be also be related to prejudice against the guitar as an art-music instrument, due to its strong presence in folk music. As Lorca recalls,

> While the Russians were burning with love of folklore, a unique source, as

[58] O.v.: Muitos escrevem quase que exclusivamente música de câmara e/ou música orquestral, pois vêm de uma cultura com forte variedade de timbre (cores). Muitos buscaram – e desenvolveram – meios de obter essa mesma qualidade com o violão solo.

[59] O.v.: Usaban la guitarra como modelo para intentar una estilización de "lenguage español."

> Robert Schumann said, of all true and characteristic art, while in France the gilded wave of Impression[ism] quivered, in Spain, a country almost unique in its tradition of popular beauty, the guitar and *cante jondo* were things for the lower classes. (Lorca, 1922/2008, p. 6)[60]

It was the guitarists themselves who, in the beginning of the twentieth century, through their own transcriptions (e.g. Francisco Tárrega), harmonizations (e.g. Miquel Llobet), or recovery of works from the past (e.g. Emilio Pujol), "tried to open up the space denied for so many years to Spain's emblematic instrument" (De Persia, 1996, p. 27).[61] According to Gilardino (1994, p. 5), it was Llobet who, in his harmonizations of Catalan folk songs, "finally specifies the timbre as the highest value of the guitar."[62] It was also Llobet's insistence with Manuel de Falla to write for guitar that led the composer to write *Homenaje* (1920) – his only piece for guitar and one of the first guitar compositions of the twentieth century by a non-guitarist – when asked to contribute with an article to a special volume of *La Revue Musicale* dedicated to the memory of Debussy (De Falla, 1926/1989, p. 1).[63] Moreover, it was Llobet who worked closely with Falla on the technical details of the piece for its definitive edition (De Persia, 1996, pp. 36-37). According to Piquer Sanclemente and Christoforidis (2009, Abstract), Falla's "new aesthetic configuration of the classical guitar" was influenced by the instrument's modernist representations in the visual arts, and provided the "impetus" for a new repertory leading to the revival of the guitar in the 1920s.

Despite the 1920s revival, institutions offering an academic curriculum in guitar were hardly a reality in the first half of the twentieth century. According to Brill (1994, p. 2), a professorship in guitar existed, nevertheless, in Vienna since 1914. In the second half of the century, the possibility to study guitar as a first instrument was introduced in 1959 in the UK, approximately a decade after guitarist Julian Bream pursued his musical studies (Goss, 2000, section II, para. 6). This guitarist was, from 1983 to 2012, the only guitarist to be featured on the cover of *Gramophone Magazine,* which is "considered to be one of the leading publications for classical

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[60] In its motherland, this situation was not new to the guitar: by mid-eighteenth-century, its "natural home … was in the humbler parts of Spanish society", as under the rule of Philip V, "the Italian musical style [had] bec[o]me strongly favoured …, the publication of new Spanish music had been largely suppressed …, and the guitar had all but vanished from fashionable middle-class theatres" (Tyler & Sparks, 2002, p. 193).

[61] O.v.: Intentaron abrir el espacio negado durante muchos años al instrumento emblemático de España.

[62] O.v.: Individua finalmente nel timbro il valore massimo della chitarra.

[63] Segovia claims, however, "that the genesis of the work [*Homenaje*] was prompted by Torroba's success with the Danza in E major" (Wade, 1980, p. 155).

music worldwide" (Reverberations, 2012, p. 6). This fact puts in evidence that the guitar has still not achieved full-status as an art-music instrument. The undervaluing of the guitar within the classical tradition is a result of various factors:

> [1] Prior to the eighteenth century, guitar music was written in tablature, an immensely practical type of notation but one that continues to obscure the repertory from most non-players ... [2] the emphasis that historians have placed on the contributions of 'great' composers – that is, whose works can be arranged as links in a long chain of influence, ... which effectively pushed guitar composers ... to the periphery of musical developments. ... [3] the artistic concept of musical 'evolution' and compositional 'worth', in which works achieve their standing and posterity through validation by musical analysis. Through this model ... guitar works [by guitarist-composers] ... are 'quantifiably' rendered 'inferior' ... [4] musicology's apprehension (until recently) to engage in the study of popular cultures (or even *culture*). (Coelho, 2003, pp. 3-4)

Regarding this last factor and as to what the guitar concerns, Coelho (2003, p. 8) acknowledges that, actually, performers like Segovia are more to blame than musicologists for the "'impenetrable' firewall around the Western art tradition." The first "essential task" to which Segovia dedicated his life was "to separate the guitar from the mindless folklore type of entertainment" (Segovia as quoted in Goss, 2000, section II, para. 5). It was, however, the folk tradition that allowed the guitar as an instrument to survive all crises along its history, stresses Miteran (1997, p. 157), who is corroborated by Turnbull:

> Each period saw the guitar elevated for a while only to sink back once more to its traditional role as a popular instrument. Far from deprecating this, one can see in it a source of strength; to continue its life as a folk instrument, the guitar had to remain uncomplicated, and one can pay tribute to those many people who, because they were unambitious in their music-making, enabled the guitar to survive long enough to become the most active and the most important fretted instrument of today. (Turnbull, 1974, p. 108)

Moreover, as Coelho remarks:

> It is difficult to see how the classical guitar could have maintained its presence without the many rock-trained students who began flocking to guitar programs since the middle 1970s, successfully transferring some aspects of their self-taught rock training (particularly left-hand technique) to classical guitar. (Coelho, 2003, p. 10)

Two recent events point towards some change in the valorisation of the guitar as an art-music instrument: the launch in 2015 by the Guitar Foundation of America of a new peer-reviewed publication entitled *Soundboard Scholar*, which aims “to publish contributions of the highest caliber in academic work related to the guitar” (Reverberations, 2013, p. 72);[64] and the launch in March 2014 of the International Guitar Research Centre at the University of Surrey.[65]

The impossible task of writing for guitar

The difficulty to write for guitar has been stressed as early as 1856 by Berlioz. According this composer, “it is almost impossible to write well for the guitar without being a player on the instrument” (Berlioz as quoted in Wade, 1980, p. 127). Guitarist-composer Stephen Goss acknowledges this, but finds that composers misinterpret the main function of the guitar:

> If you’re an outsider wanting to write for guitar, it’s a steep learning curve. It’s not like learning how to write for saxophone, for argument’s sake. With a wind instrument, you learn the range and fingering charts, the qualities of the different registers, what’s comfortable and what’s not comfortable, how certain articulations and effects are executed, what the balance issues are, and off you go. With guitar, there is a lot more tacit knowledge to unpick. Very few non-guitarist composers have really understood the idiom well. ... Many composers fall into the trap of thinking of the guitar as first and foremost a harmonic instrument. I think of the guitar as a melody instrument, more a violin or a cello with extra possibilities of resonance, than as a piano with debilitating limitations. (Traviss & Goss, 2013, p. 30)

Composer Rafael Nassif is also of the opinion that the guitar's multiple functions – harmonic, rhythmic, and melodic – tend to leave unclear which should be its usage. For him, the guitar to be a "textural instrument", since "it intertwines and juxtaposes the frontiers of the organisational parameters of musical thought" (Nassif, 2010, (um pouco sobre) "silhuetas ...", para. 1).[66]

The peculiarity of the guitar is not taken into account in the programs of composition degrees. In fact, the guitar receives less attention than other instruments, recalls composer Clarice Assad, who stems from a family of guitarists:

> It's not easy to write for guitar if you have no idea of what the instrument really is. If you're in college studying to become a composer, you study a lot of new music, classic, but you never see a line written for guitar. It's rare. So,

[64] By the time of the submission of this thesis, the first number was still to be published.

[65] Webpage: http://www.surrey.ac.uk/schoolofarts/research/guitar

[66] O.v.: Soa de efeito como um instrumento textural, já que imbrica e justapõe as fronteiras dos parâmetros de organização do pensamento musical.

> composers who are walking around don't even think about it. In orchestration classes, there is only a sad, limited portion about the guitar. It's not emphasized, so it becomes a monster with seven heads for people who want to write for it but don't know the sound of the guitar. I know where the fingers are if I hear an arpeggio because I heard it too many times. It's part of my musical vocabulary; I grew up listening to it. But for most composers it's ridiculously hard to write for guitar. (Durek & Assad, 2012, p. 112)

Non-guitarist composer Vito Žuraj confirms Assad's words:

> The guitar is not a standard instrument in the orchestra and thus I have not yet found out what to write for it. And it is technically special so that, as a composer, one has to come into contact with it before one can write something good for it (V. Žuraj, personal communication, Jan. 16, 2012).[67]

Guitarist Christian Rivet corroborates the statements of Assad and Žuraj:

> It is a very idiomatic instrument and to make it sound it is in fact almost necessary to play it. … there is a terrible, terrible fear because it is difficult to make the instrument sound in a way... … it is complicated, it is difficult to make the instrument sound. (Bruneau-Boulmier & Rivet, 2011)[68]

The limitations of the guitar

The guitar is often dismissed for its limited technical and acoustical possibilities. For Del Busto (1998, p. 130) the guitar is more limited "not only in the technical possibilities, but also in the composers' knowledge on those possibilities, in its years of existence as a concert instrument, in its geographical expansion and thus in its repertory",[69] being these the reasons why the "weight" imposed on composers by tradition is heavier when writing concert pieces for the "'Spanish concert guitar.'"[70] In fact, composer Brian Ferneyhough (n.d.) writes about the task of inscribing his language "into the rigorous limits of the historically and physically delimited 'text' of the guitar." In other words from him in what regards the latter limitation: "How violence, mass and gestural emphasis could be carried across from my previous

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[67] O.v.: Gitarre ist kein Standardinstrument im Orchester und ich kam daher noch nie dazu, was dafür zu schreiben. Und es ist technisch speziell, so muss man sich als Komponist schon genau damit befassen, bevor man was gutes dafür schreiben kann.

[68] O.v.: C'est un instrument très idiomatique, pour le faire sonner il faut vraiment casimment le jouer. ... il y a un peur terrible, terrible. Parce que c'est compliqué pour faire sonner l'instrument d'une manière... ... c'est compliqué, pour faire sonner l'instrument c'est difficile.

[69] O.v.: ... instrumento não apenas muito mais limitado ... quanto a recursos técnicos, mas também muito mais limitado quanto ao conhecimento real desses recursos por parte dos compositores, quanto ao tempo de existência concertística, quanto à sua expansão geográfica e, portanto, quanto ao seu repertório.

[70] O. v.: peso; "guitarra espanhola para concerto."

practice into the acoustically restricted universe of the guitar" (Ferneyhough, 1995, p. 152). The acoustical limitations of the guitar are also stressed by composer Tristan Murail: "With the guitar there is not mass nor either the sustain of the sound" (Andia & Murail, 1984/n.d., answer 4); and recalled by Schneider (1985, p. 104): "The guitar has always been criticized as musically insignificant because of its poor timbral and dynamic range." This "poor timbral range" is, however, not intrinsic to the instrument but due to the lack of colour research.

The Segovia sound

> Initially, Segovia's promotion of the guitar injected a 'noise' into the concert music tradition, in the sense that it introduced a new, disruptive type of sound into the rarified world of concert music Gavin Carfoot[71]

Segovia introduced a new timbre in concert halls, but this was a very limited timbre because, due to his conservatism, it was associated to a very specific kind of repertoire. This consisted of transcriptions, in some older works, and of new compositions of "post-romantic impressionistic coloured music influenced by hispanic-folk music" (Pfäffgen, 1988, pp. 190-191).[72] This *sound* became paradigmatic and quite distasteful to some composers, like Murail:

> My impression is that the traditional guitar such as one usually hears it is a treason of the original instrument: in fact it is a product of the XIXth century. People wanted to imitate the other instruments and to make guitar something sizeable, i.e. able to play classical music. The guitar is in the beginning an "ethnic" instrument. Of Arab origin (quitara), it is used in Spain to play the Arabo-Andalusian music and flamenco, but with a very different technique which leads to very different sounds: those I use in *Tellur.* What I like in the guitar, it is precisely not the guitar of SEGOVIA, its polished and decorous side, but the use that one makes in flamenco and also in Latin-American music, although I'm not crazy about these musics for themselves. (Andia & Murail, 1984/n.d., answer 1)

[71] In G. Carfoot, Acoustic, electric, and virtual noise: The cultural identity of the guitar, p. 36.

[72] O.v.: Hispanisch-folkloristisch beeinflußte, nachromantisch-impressionistisch gefärbte Musik.

The guitar's wicked step sister

> Following the gradual acceptance of the instrument in th[e concert music] setting, much writing about the guitar in the early and mid-20th century aimed to reinforce the development of an orthodox concert tradition. The development of the electric guitar in the 1940s and 1950s came as something of a threat to this ideology.
>
> Gavin Carfoot[73]

The creative and musical possibilities of the electric guitar were dismissed by some as late as 1974 (Carfoot, 2006, p. 36). "Paradoxically, the long sought academic acceptance of the guitar into the musical mainstream has come not with the classical guitar, but with the electric guitar" stresses Goss (2000, section IV, para. 6). This was perhaps because, as guitar maker Manuel Contreras II points out, whereas the classical guitar "is a very demanding instrument to master and it just does not suit everyone[, m]ost people can get something out of an electric guitar" (Contreras as quoted in Dawe & Dawe, 2001, p. 73). In the art-music scene it is not uncommon to find composers who have used the electric guitar – mostly in ensemble[74] – but never the classical guitar. The preference of composers for the electric guitar might be related by its technological possibilities. According to Lähdeoja, Nacarret, Quintans, and Sèdes (2009, Abstract), the electric guitar is an instrument of technological innovation: this "augmented (and augmentable) instrument"[75] was the first instrument to benefit from the MIDI protocol and to have been connected to a computer via an analog-to-digital interface. Moreover, as "the sociocultural ideologies that are inscribed in musical instruments cannot be divorced from those instruments", the preference for the electric guitar might also be related with the fact that the ideology surrounding it is associated with "the incursion of 'chaotic noise'" (Carfoot, 2006, pp. 36, 38). Furthermore, it is also "intimately tied to discourses of gender, race, age and generation, nostalgia, and the powerful effect of sound itself" (Carfoot, 2006, p. 36). This is, in fact, the case of composer Luís Pena, who is yet to make use of any kind of guitar in his work and would choose the (classical) "guitar's wicked sister" because it "has a different 'coolness' factor and brings [to the music] an aura of subversion which many prefer" (L. Pena, personal communication, October, 13, 2013).[76] Should he have a performer to work with, he would write for the classical guitar (L. Pena, personal communication, November, 22,

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[73] In G. Carfoot, p. 36.

[74] A search at http://www.sheerpluck.de/search.php for pieces for/with electric guitar gave as result 3 pieces for its solo usage against a total of 5087. Accessed October 15, 2013.

[75] O.v.: instrument augmenté (et augmentable).

[76] O.v.: Irmã má da guitarra ... Essa tem um factor de "coolness" diferente e traz consigo uma aura de subversidade que é em muitos casos preferida.

2011). Pena's reasons for not having used it up to now include not having studied it in orchestration classes, and, given its weak projection, the difficulty in combining it with other instruments (L. Pena, personal communication, October, 13, 2013).

2.2.5 Promoting colour research

> The only way in which the guitar ... can maintain its position in the realm of serious music, is for it to be cultivated by enthusiasts who make a thoroughly musical, as well as practical approach to its technique and possibilities.
> Julian Bream[77]

To expand the sonorous possibilities of the guitar, it is necessary that non-guitarist composers engage in writing for the instrument. Ways in which this is being, or could be, achieved are discussed below.

A secure patronage

Given the mechanisms through which music history is constructed, “the secure patronage of great composers”, which most other European instruments enjoy (Wade, 1980, p. 216), could help avoiding prejudice against the guitar as an art-music instrument. This is especially significant when looking at younger generations who tend to deify established and successful composers. Engaging in guitar composition may end up being rewarding for these composers, like it was for Alberto Ginastera:

> When the critics at its premiere received this work [Sonata Op. 47] as one of the most important ever written for the guitar, as much for its conception as for its modernism and its unprecedented imaginative use of sound, I though that I had not waited in vain for several decades to make the attempt. (Ginastera as quoted in Wade, 2001, p. 162)

Commissioning and collaboration

Commissioning is a form to promote the writing of new works, especially by more renowned composers, who have enough commissions to even consider writing for free. For Morris, commissioning guaranteed the guitar “a future away from the ghetto in which it found itself at the end of the nineteenth century” (Nonken & Morris, 2002, p. 18). Given the difficulty of guitar composition, it is important to associate with the commission the collaboration of a guitarist. As Goss stresses, “significant collaborative input from a guitarist is absolutely crucial for most non-guitarist composers” (Traviss & Goss, 2013, p. 30). The above-discussed example of Bream proves this to be fruitful. Like him, the collaborating guitarists are often the initiators

[77] As quoted in G. Wade, *A concise history of the classic guitar*, p. 144.

of the commissions, and occasionally also the patrons:

> We [*ChromaDuo* (guitar duo)] decided that one of the main ways for us to make a contribution was to commission. We both have a passion for new music, and recognize that the repertoire needs constant re-vitalization if the guitar is to survive and thrive. Additionally, we see a fair number of composers languishing in obscurity, not knowing how to market themselves or their often beautiful and challenging music, while others who might easily create a slick presentation shy away from the risk involved in writing for such a labyrinthine instrument as ours—at least without a trusted guide.
>
> By devoting ourselves to composers of twenty-first century music, whether on a small or large scale, we can potentially make an enduring contribution to the repertoire of our instrument. (Smith, 2013)

If the collaborating guitarist is conservative and lazy, colour research will, however, most certainly not take place. It is essential for the promotion of colour research that the guitarist is adventurous and has a good arsenal of performace techniques.

In the case of the guitar, commissioning is also a cry for attention. The collaboration with guitarist Christoph Jäggin made Fritz Vögelin (1987) “quite acquainted with an instrument, with which [he], until then, had had little contact” (Corrigenda[78]).[79] After working with Bream, Hans Werner Henze ended up with “a deeper knowledge of the guitar's sonic and technical aura, and even perhaps a new vision on writing for instruments with a rich tradition” (Henze as quoted in Pfäffgen, 1988, p. 204).[80] Ferneyhough (1995, p. 148) “had not been much concerned with the guitar” before Magnus Andersson asked him for a piece. In this case, however, there was no collaboration, as this is something with which Ferneyhough never felt comfortable; stimulated “by the challenge of unfamiliar 'theaters'”, he prefers to “thoroughly” investigate the instruments – for him the guitar has proved to be “especially demanding” (p. 410).

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[78] Supplied by Christoph Jäggin.

[79] O.v.: Er brachte mir das Instrument, zu dem ich bis anhin wenig Beziehung hatte, sehr nahe.

[80] O.v.: ... Zusammenarbeit mit dem Instrumentalisten, aus der ich eine vertiefte Kenntnis der klanglichen und technischen Aura der Gitarre zurückbringen konnte, ja, vielleicht sogar eine neue Vorstellung vom Schreiben für traditionsreiche Instrumente.

Exploring unconventional performance techniques

> One does not dismiss the bowed and wind instruments on account of their essentially monodic quality. Similarly, one must not expect the harmonic possibilities and volume of a piano when considering the guitar. It is essential to evaluate the instrument on its own terms, and explore what is capable of achieving.
> Harvey Turnbull[81]

New results from the exploration of unconventional performance techniques could entice composers dismissing the guitar for its paradigmatic sound and its limitations to reconsider composing for the instrument. This is because unconventional techniques not only give rise to unusual colours but can also be useful in overcoming limitations. For Lachenmann (2004), writing for guitar is about impregnating its typical sound with his own means and vice-versa (p. 157). In *Salut für Caudwell* for two guitars (1977), he "departed from the characteristic playing styles of the guitar, simplified them drastically on the one hand, and on the other hand transformed and developed them, often beyond the limits of the usual practice" (Lachenmann, 2004, p. 157)[82] One of these unconventional techniques is the bottleneck *glissando*, with which Lachenmann might not only have desired to overcome the guitar's "imposed [equal] temperament", as Ribeiro (2012, p. 9) stresses,[83] but also its *discreteness*, that is, its stopped-pitch discontinuity. This discontinuity is, however, for composer Georg Friedrich Haas (2012), an advantage when using different tunings, in the sense that intonation is more easily achievable than in fretless instruments. Haas used, in fact, different tunings in *Quartet* for guitar quartet (2007), to produce microtonal sonorities, and avoid the paradigmatic sound of the guitar. This was also the approach of Ferneyhough (1995) in *Kurze Schatten II* for guitar (1983-1989), in which, moreover, the tuning changes during the piece, "gradually transformi[ng] the resonance of the work over its total duration" (p. 139):

> At the conclusion of every second piece one string is returned to normal, so that by the seventh movement only one string (B natural) is still detuned (to Bb). (p. 400)
> The final note is, appropriately, a natural harmonic Bb; a pyrrhic victory, perhaps, for the defamiliarization principle over the ineluctable encroachment, from panel to panel, of 'normal' guitar sonority. (Ferneyhough, 1995, p. 152)

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[81] In H. Turnbull, *The guitar: From the Renaissance to the present day,* p. 123.

[82] O.v.: In diesem Sinn bin ich von characteristischen Spielformen der Gitarre ausgegangen, habe sie einerseits lapidar reduziert, anderseits umgeformt und neu entwickelt, oft über die Grenzen der üblichen Praxis hinaus.

[83] O.v.: Temperamento imposto.

Oriol Saladrigues (2005) also requests non-tempered tones, but these are produced by playing the part of the string between the finger and the nut. The other reason for using these tones in *Mur* for amplified guitar (2005) was the change in colour: “The idea was to achieve an effect of distance and blurring of the reality, as if there were two guitars, one close and the other on the other side of the wall (*Mur* in Catalan means wall)” (O. Saladrigues, personal communication, March 26, 2011).[84] The intention of Saladrigues when using amplification was, however, “only” to make those sounds more audible – he did not mention the further change in colour this might imply.

It is also possible to overcome limitations through conventional techniques. To produce “the generally brusk violence of [his] vernacular”, Ferneyhough (1995) sought “gestural areas which were amenable to collecting and explosively releasing energies 'in miniature', rather analogous to the violent *effect* (but factually low *amplitude*) of a very pronounced flute key click” (p. 400). Another of Ferneyhough's solutions to achieve violence and mass was a “miniaturization of formal and temporal dimensions” (p. 152): in the last movement, “in a surrealistically miniaturized time frame, ... practically every conventional device of traditional guitar usage may be encountered” (p. 151). A “fundamental resource” in the creation of polyphonic layers, was for Ferneyhough natural harmonics, as “once attacked, the left-hand finger is removed and thus made available for use on some other string” (p. 141).[85] In turn, most techniques in Murail's *Tellur* for guitar (1978) are inspired by the techniques of the flamenco guitar, to which the sound of the piece should be closer (Murail, 1978, introduction). As the composer explains, by means of a continuous *rasgueado*, he overcame the problem of sound maintenance, and avoided the “guitar of Segovia”, (Andia, 1984/n.d., Techniques, para. 1).The latter was moreover also attained by the use of different tunings (Murail, n.d., last para.). The continuity of the gesture or its systematic repetition together with the use of different tunings, leads to its “decontextualization”, as Ribeiro (2012, pp. 3-4/15-17) stresses. Connotation with the flamenco guitar, a goal for which, as Andia (1984/n.d., Conclusion) stresses, the *rasgueado* tends to be used, is thus avoided. A repeated *rasgueado* can also be found in Berio's *Sequenza XI* (1987-1988), which is for its dedicatee “remarkable[,] particularly for a non-guitarist composer in that its considerable technical difficulties are somehow still idiomatic" (Fisk as quoted in Wade, 2001, p. 185).

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[84] O.v.: La idea era de conseguir un efecto de lejanía y difuminación de la realidad, como si hubiera dos guitarras, una cerca y la otra "al otro lado del muro" (Mur, en catalán, significa Muro).

[85] This is also true for multiphonics.

Exploring unconventional techniques with amplification may expand their timbral possibilities. It changes, however, the identity of sounds that are more limited in colour, because what reaches our ears is projected in only one direction. It is like "a ray of concentric light",[86] whereas the way instruments radiate sound is like that of "diamonds lit up by a beam of light" metaphorises Stroppa (Béros, Dautrey, Donin & Stroppa, 2010, p. 174),[87] who solves this "dissonance" present in pieces of mixed music, by using small loudspeakers close to each other and oriented in different directions. Moreover, the presence and energy of the original sound are lost, stresses Furrer (2011). The “individuality of the instrument” is “changed by technology” and it becomes, in fact, a “*different* instrument”, stresses Turetzky (1989), who points out that some transducers have the tendency to make all registers sound even, the amplifier eventually changes the timbre and colour, and the loudspeakers make “the $100 instrument sound just like the $1000 instrument” (p. xi).

For a different instrument, a different playing technique is needed. The French ensemble *Le Balcon* amplifies every piece it plays, even if amplification was not intended. According to its conductor Maxime Pascal, this is done to practice the amplified playing technique, which is “quite difficult and needs savoir-faire” and is needed in pieces of mixed music. The latter he sees as a “tool”, which “has not yet been subdued by composers nor interpreters … because we are still in the very beginning”, compared for example with the tradition of composing and of interpreting orchestral or string quartet music (Derrien & Pascal, 2011). In addition, a different compositional approach is needed. Inglefield and Neill (1985, p. 63) stress the fact that most of the pieces that require the harp to be amplified “do not really take advantage of sounds that can be produced with amplification.” When writing for the amplified instrument it is important to introduce novelty in order to have enough distance from the non-amplified instrument. For Billone (2011), a sound in a context (for example, religious) has a meaning and a sacrality, and it would make no sense to use it as compositional material in another context. If this took place, hearing the dislocated sound would give rise to its connotation with the original context. In this sense, if the amplified sound did not introduce novelty, the listener would hear it as being related to the non-amplified sound, and perhaps be disappointed. Regarding the amplified guitar, or any amplified instrument with decaying sounds, when these are left to decay away, the primary novelty that is introduced is the perception of a longer lasting decay. For itself it is not much, but it can aid the fruition of other

[86] O.v.: Une rayon de lumière concentrique

[87] O.v.: Des diamants éclairés par un faisceau de lumière.

sounds the amplification of which introduces novelty in colour. As is shown in this thesis, this is case of the sounds of multiphonics.

2.3 Guitar Multiphonics

Contrary to woodwind and bowed-string multiphonics, research on guitar multiphonics has only recently received renewed attention. It is then not surprising to still find players and composers that are not aware of this technique's executability on the guitar, or that do not know how to do it, as put in evidence by an online-forum discussion on classical-guitar multiphonics (Aum, Tarbaby, sbondy, anacrusis, chien buggle, & Fredonia_Guitar, 2012). It would be also not surprising to find guitarists who, in the absence of relevant information, may simply be categorically dismissing this technique. Section 2.3.1 revises scientific literature dealing with guitar multiphonics, as well as artistic literature making use of it, and discusses their gaps. One of these gaps is the lack of a detailed explanation on the acoustics and psychoacoustics of multiphonics. For which, this was formulated based on literature, and can be found in section 2.3.2. In section 2.3.3, the research question is posed and a hypothesis is formulated.

2.3.1 Literature

Scientific literature

To the knowledge of the author, monographs on guitar multiphonics do not exist. The works in which information is more exhaustive are those on unconventional performance techniques on the guitar. The first of this kind of books was possibly that of Mas (1984), who does not deal explicitly with multiphonics, but lists also as harmonics locations those at which the technique of multiphonics is also, or in fact, only possible (pp. 28-30). Rebizzi and Tajè (1987), Lehner-Wieternik (1991) and Lunn (2010) also deal with unconventional techniques without mentioning multiphonics. Below, literature dealing with this technique is reviewed by date of publication. This is followed by a discussion of its gaps.

Andia – How to Write for Guitar: An Explanation for Non Guitarist Composers (1983)

In a document for non-guitarist composers,[88] Andia (1983) was possibly the first to apply the term *multiphonic* on the guitar technique. However, he only uses it in regard to the possibility of using an extremely light pressure at conventional

[88] This document will be published as a book in the near future (R. Andia, personal communication, September 11, 2014).

harmonics locations (see section 2.3.2):

> This is a technique to obtain two sounds more or less simultaneously from a single string. [It is] a matter of an open string and one of its rank of higher natural harmonics. Possible only on some isolated notes. By rapidly producing these multiphonics, two to each string, one can stack up to a dozen sounds on a standard six strings guitar. (Andia, ca. 2002, Multiphonic sounds)

Andia lists the possibilities by notating them for each string, and supplies four audio examples.

Schneider – The Contemporary Guitar

In this book on unconventional performance techniques (accompanied by two "sound sheets" with examples), Schneider (1985) starts by contextualising the subject and giving an explanation for the phenomenon (pp. 135-136). He then proceeds to suggesting a notation: "Multiphonics should be notated by ... (a tilted double-sharp sign), with the string number and fret placement; the note-head should lie on the staff where the note would sound if the finger were pressed to the fingerboard" (p. 136). However, he does not depict an example and gives instead the verbal example "[encircled] 6 ¼ XIX" which is supposed to mean (thus, it has a typo): touch the string between frets VIII and IX at the point that is distanced from fret VIII one quarter of the length of the space between those frets (in the absence of a fraction the touching is at the fret) (p. 136). Finally, he supplies a "Chart of multiphonics on the bass strings" (p. 137). This chart depicts the position on the string of 14 touch locations (13 of which at the fretboard) at which multiphonics can be played, and, for each location, two, three, or four pitches (aurally verified). Nine different sounds arise from playing at these locations, since some locations are the symmetrical counterpart to others. The note heads of the loudest partials are white diamond-shaped, and those of weaker partials are black, either diamond-shaped or round (the weakest). Microtonal accidentals are used for partial 13.[89] Schneider gives two examples by the same composer, and finishes the section encouraging the use of multiphonics: "these new sounds should become a part of the guitar's vocabulary as composers find good musical uses for them" (p. 138). The novelties of the revised and enlarged edition of this book (Schneider, 2015), which was published shortly before the submission of the present thesis, are essentially two other examples (that of Sor's *Fantasie*, and another on the electric guitar), and reference to literature with further examples and on scientific research on multiphonics.

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[89] These accidentals are the same as those found in Alois Hába's music for 1/4, 1/5 and 1/6 tone alterations (Zeller, 2003, pp. 222, 243).

Leathwood – Some Notes on Writing for the Guitar

A document for non-guitarist composers by Leathwood (2010) includes a short section on “multiphonic harmonics” (p. 15). “Fascinating sounds emerge when one attempts to play a natural harmonic somewhere other than a simple fraction of the string’s length” starts Leathwood. He then describes the sounds as a combination of “more than one pitch with a healthy dose of percussive noise.” The example provided is for fret VI and depicts two pitches – notated with diamond-shaped note heads –, and the noise component – notated below the staff with a cross-shaped note head. Composers have hardly taken up these sounds, stresses Leathwood at the end of the section.

Gimeno – Los Armónicos en la Música para Guitarra

In this encyclopedia entry on harmonics Gimeno (2011) dedicates a short section to harmonics at unusual nodes. He gives only the example of Sor's *Fantasie* (see the beginning of this chapter), explaining that “two harmonics can be perceived” in the sound, which “is usually called a multiphonic sound” (p. A78)[90]

Vishnick – A Survey of Extended Techniques on the Classical Six-String Guitar with Appended Studies in New Morphological Notation.

In the multiphonics section of this doctoral thesis, Vishinick (2014) starts by explaining the acoustics of the sounds through quotations by other authors (p. 239). He then illustrates the sonic result with an audio example, and by “describing the morphology produced on string 6, fret VI” (p. 240). Vishnick suggests 13 multiphonics locations, all between the nut and fret XII, and presents them in a chart of “natural and multiphonic harmonics” (pp. 221-225), which depicts the position on the string of the touch locations and two to four resulting pitches. The locations are identified as follows:

- Harmonics on frets are indicated as Roman numerals only, VI for example;
- Positions just before frets are termed (L) and just after frets (R), III_{L} and IV_{R} for instance;
- A mid-fret position is indicated as follows- III/IV;
- Positions between just before and mid are termed (LL)- II_{LL}, between just after and mid (RR) – II_{RR}. (p. 221)

The note heads in Vishnick's chart differentiate three loudness levels: softest

[90] O.v.: Pueden apreciarse ... dos armónicos ... estamos ante lo que suele llamarse un sonido multifónico.

(rectangular-shaped, white), medium (diamond-shaped, black) and loudest (diamond-shaped, white) (p. 221). Focusing on the notation used, Vishnick gives examples of multiphonics usage by four composers (p. 240). He then suggests a notation, and an exercise to gain “preliminary experience in multiphonic harmonics playing” (pp. 240-241). The section ends with explanations for Vishinick's three multiphonic harmonics studies (pp. 241-245).

Josel and Tsao – The Techniques of Guitar Playing

Josel and Tsao (2014) start the multiphonics section of their book (which includes a CD with audio examples) with a brief explanation for the sounds' acoustics, relating it to the trombone's split tones. They summarise it as: “every multiphonic will be some combination of natural harmonics on a given string; this combination will be determined by those harmonics that have nodes near where the finger touches the string” (p. 118). In regard to notation, these authors

> recommend that a multiphonic be notated in terms of its fingered position on the guitar, including the string number, and with a separate stave showing the concert pitches above the fingered note. The recommended notation for the fingered notes is a diamond-shaped notehead (to indicate harmonic left-hand pressure) with an "x" through the notehead to distinguish it from a natural harmonic. (p. 118)

Josel and Tsao authors point out as “essential parameters” for the production of the sounds the touch location and the “plucking position and manner of plucking” (p. 119). They supply two charts for “reliable” and “relatively responsive” sounds on strings 4 to 6, stressing that the charts are not exhaustive: “Their purpose ... is merely to give possible multiphonic chords for a composer or performer to use” (p. 119). The first chart (p. 120) depicts the position on the string of the 18 selected multiphonics locations (17 of which are at the fretboard), and of the string nodes up to those of v.m. 19. Each location has a “position number” that “correlates to a chord, which is annotated” in the other chart (p. 119). The position number consists of

> Roman Numeral= Fret number
> Arabic Numeral= ¼, ½, ¾ of the distance up (towards the bridge) between the two neighboring frets
> -, + = slightly to the left or right respectively of the indicated position. (p. 121)

In the chart, however, instead of fractions the decimal numbers “.25”, “.5” and “.75” are used. The second chart (p. 121) provides, for each touch location, the following information:

> (a) The concert pitches of each multiphonic chord (all of which will be harmonics based on the open string)

> (b) Beneath each chord, the numbers of the harmonic series of the pitches involved
> (c) to the [left] of each chord, the stopped pitch for executing the multiphonic
> (d) The string number at the beginning of each figure
> (e) The relative amplitude of the pitches in the chord [white or black noteheads differentiate respectively strong and weak pitches]. (p. 119)

Quarter-tone accidentals are used for the notation of locations halfway between frets, as well as for the pitches of partials 11 and 13. For locations “slightly” to right or to the left of the frets, and for the pitch of partial 7 they use chromatic accidentals with arrows (p. 121). The information relative to the pitches stems from spectral analyses of the sounds carried out with three different guitars: two classical guitars and one steel-string guitar (p. 211). The analyses were based on

> readings at three different times during the morphology of the multiphonics sound: 100-150 milliseconds, 400-500 ms, 800-1000 ms. The resultant chords in [the depicted] Figures ... were derived from those harmonics that were present over the entire course of the multiphonic's morphology. However, [their] analysis revealed that the strength of each chord's harmonics changed over time in that weaker harmonics occasionally gained strength as the multiphonic sound evolved. (pp. 211-212)

The highest pitch they supply is that of partial 19, apparently because higher partials are “rarely audible” (p. 119), and not because they eventually did not last one second. The authors finish the section by giving examples of multiphonics usage by five composers (pp. 123-125).

Discussion

All reviewed publications lack a detailed explanation of the acoustics of multiphonics. This is not unusual, as Fallowfield (2010) stresses: “an insufficient link between action and sound is a most basic and serious problem, but it is widespread and occurs especially in the case of new techniques … The link between actions and sound is acoustics” (p. 33). It is important to acquire technical knowledge on sound production because, just as a minimal change in orientation of a telescope changes completely the picture observed, a minimal change in sound production may give rise to a completely different sound (Billone, 2011). Therefore, Fallowfield chose to present information in

> a continuous way, showing how, for each step along a scale of actions, a musician can change sound, control fine detail and understand the possible sonic variation within a wider categorisation of technique. ... providing a basis for personal experimentation on the part of the performer and composer] and

for further research. (Fallowfield, 2010, pp. 18-19).

As will be discussed in subsection 2.3.2, continuity is possible in multiphonics, both for touch and excitation locations and other playing conditions. Notwithstanding, the locations that the authors suggest are just a few of the many possibilities. One of the criteria of Josel and Tsao (2014) for the selection of locations was the sounds being reliable (p. 119).[91] The period of time they established therefor was of one second (p. 211), which is quite long. By considering a shorter period of time, it should be possible to take into account a greater number of locations because fewer partials have died away (higher partials have shorter decays [Meyer, 1985, pp. 9-10]). The locations suggested in the reviewed publications are listed in Table 2.1 with the ID that the authors chose for the locations, and the pitch content that they provide for the resulting sounds. Most locations suggested by Vishnick (2014) are possibly meant to be the same as those suggested by Schneider (1985). Vishnick provides the same pitch content for locations that, however, are graphically not at the same fretboard position as those by Schneider. As in Vishnick's chart there is no proportionality in the distance between frets, it is to assume that there was no accuracy in the exact positioning of the locations he took from Schneider.

The pitch content provided the authors is based on the execution of a single player (mostly on a single instrument). This presents a problem, as each player has his/her own instrument, physiognomy and idiosyncrasies, and this may influence the resulting sounds. Some players may not even be capable of producing them. The information on the sounds should then contain the influence of the differences of the instruments and of the players. Moreover, when the information supplied is based on spectral analysis, as is the case of Josel and Tsao (2014), the sound pick-up and analysis conditions should be provided, and psychoacoustics should be taken into account. Finally categorising the sounds, which none of the authors carried out (nor have they proposed descriptors therefor), is helpful in selecting sounds.

Artistic literature

Literature making use of multiphonics is reviewed thematically below. This is followed by a discussion of its gaps.

The earliest piece after Sor's *Fantasie* (see the beginning of this chapter) asking for multiphonics is possibly Bruno Bartolozzi's *Auser* for oboe and guitar (1972). Bartolozzi also made use of the technique in *Repitu* for flute, viola, guitar and

[91] The Institute of Electrical and Electronics Engineers (1990, p. 170) defines reliability as "the ability of a system or component to function under stated conditions for a specified period of time."

Table 2.1. Multiphonics locations suggested in the reviewed scientific literature
A: Andia;[92] S: Schneider;[93] L: Leathwood;[94] J&T: Josel and Tsao;[95] V: Vishnick.[96] The locations are organised from nut to saddle. Their numbers (No.) was attributed by the present author according to similarities of position or partial content. This is also the case of the identification (ID) of the locations suggested by Schneider, which follow his own nomenclature. Partials notated as weak are in italic.

No.	Author	Location ID	Pitch content (partial nos.)	No.	Author	Location ID	Pitch content (partial nos.)
1	J&T	I.5	11, 12, 13	15b	V	VIII_{R}	5, *8*, 13
2	J&T	II-	9, 10, 11, 19	16	J&T	VIII.5-	5, 8, 13, *18*
3a	S	¾ III	6, 7, 13	17a	S	¼ X	5, 7, 12
3b	V	III_{L}	6, 7, 13	17b	V	IX_{R}	5, 7, 12
4	J&T	III-	6, 7, 13,*19*	18	J&T	IX.5	5, 7, *12*, *19*
5a	S	⅓ IV	5, 6, 11	19a	S	⅔ X	7, *9*
5b	V	III/IV	5, 6, 11	19b	V	X_{L}	*7, 9*
5c	J&T	III.5	5, 6, 11,*16*	20	J&T	X	7, 9, *16*
6	A	[IV]	1, 5	21a	S	⅓ XI	*7,* 9
7a	S	¼ V	4, 5, 9, 14	21b	V	X_{R}	*7,* 9
7b	V	IV_{R}	4, 5, 9, 14	22	J&T	X.75	*2*, 11, 13, 15, *17*
8a	V	IV/V	4, 5	23	V	XI	8, ?
8b	J&T	IV.5	4, 9, 13, *17*	24	A	[XII]	1, 2
9	S	½ VI	4, 11, *16*	25	S	¾ XIV	*7,* 9
	V	V/VI	4, 11, *16*	26	J&T	XIV-	*2*, 9, 11, *13*
10	J&T	V.5+	4, 7, 11, *18*	27	J&T	XIV.25	*2*, 7, 9, *16*
11	L	n/a	3, 7	28	S	⅓ XV	7, *9*
	S	VI	3, 7, 10, *17*	29	J&T	XV.25	5, 7, *12*, 17
	V	VI	3, 7, 10, *17*	30	S	½ XVI	5, 7, 12
	J&T	VI	3, 7, 10, *17*	31	J&T	XVI.5	5, *8*, 13, 18
12	A	[VII]	1, 3	32	S	⅔ XVII	5, *8*, 13
13	V	VIII_{L}	4, *5*	33	J&T	XVII.5	3, 8, 11, *19*
14	J&T	VIII	3, 8, 11, *19*	34	S	XXIII	3, 7, 10, *17*
15a	S	⅓ IX	5, *8*, 13	35	J&T	XXIV+	4, *9*, *13*, *17*

percussion (1975b), and in *Adles* for guitar (1977).[97] In both *Auser* and *Adles* three sounds of multiphonics (different in each piece, all on string 6) have the same formal function of introducing a slow section of the piece. In *Auser*, each sound is used once, and is long and articulated alone; between the second and third sounds there

[92] R. Andia, *How to write for guitar*.

[93] J. Schneider, *The contemporary guitar*, p. 137.

[94] J. Leathwood, *Some notes on writing for the guitar,* p. 15.

[95] S. Josel and M. Tsao, *The techniques of guitar playing*, pp. 120-121.

[96] M. Vishnick, *A Survey of extended techniques,* pp. 221-225.

[97] According to guitarist Christoph Jäggin (2013, personal communication, March 24), Bartolozzi also requests multiphonics in *Memorie* for three guitars and orchestra (1975).

is a group of three notes (Bartolozzi, 1975a, p. 3). The sounds in *Adles* (all on string 6) are also articulated alone but the first sound is repeated in the end, and all are left to ring while other sounds are played (Bartolozzi, 1979, p. 2). In *Repitu*, the same first two sounds of *Auser* are each articulated once together with the tam-tam, left to ring therewith, and alternated with viola multiphonics – this accompanies a line of the flute (Bartolozzi, 1975b, p. 6). In all three pieces, Bartolozzi notated the string numerically and the fretboard location with a pitch symbol, using microtonal accidentals for locations between frets. He includes resulting pitches in parentheses, as in Fig. 2.3.

Some authors have asked for multiphonics exclusively at frets, or at frets and at halfway between frets. The former case is that of Beat Furrer in *… Y a una Canción Desesperada* for three guitars (1986; two guitars have scordatura) and of Thierry Blondeau in *Non-lieu I* for solo guitar (1998). The latter case is that of Claudio Ambrosini in *RAP* for guitar (1994) (Josel & Tsao, 2014, p. 124) and of Blondeau in *Tel/f@x.comTM*, a piece of the cycle *Pêle-mêle* for ensemble and electronics (1998-2004). In the piece of Furrer (1997), the sounds are short and mostly articulated alone, and rapidly follow and are followed by sounds of harmonics (p. 3). Furrer notated multiphonics with only the touch location pitch symbol, and harmonics with only the resulting pitch. However, the multiphonics requests only become explicit in the performance notes: when pitches are notated with a diamond-shaped note head, the numerically notated string is to be touched as it is in the technique of harmonics. This gives rise to a “multiphonic, poignantly noisy sound” explains Furrer (performance notes).[98]

Like Sor, to evoke the sound of a bell was presumably the intention of Blondeau in *Non-Lieu* I: “You tune the instrument then start an attempt at exhausting the guitar’s harmonics. ... Bit by bit you approach the chord of a bell” (Blondeau, 2009, p. 12). In two moments of this improvised piece, written “on holiday, far from home”, being left with nothing but a guitar after “the computer has broken down” (Blondeau, 2009, p. 12), Blondeau (2000) requests multiphonics at frets, and at hypothetical frets between the last fret and the saddle in two moments of the piece (pp. 7, 9). The sounds are articulated alone, are short in the first moment and left to ring in the second, and rapidly follow and are followed by sounds of harmonics or other sounds of multiphonics. Blondeau notated both fret and string with symbolic pitch notation, and used the same notation for harmonics. However, while in the latter a pitch is notated in the chord of action-symbols, in multiphonics only an encircled M is attached to it. An example of this notation can be found in Fig. 2.4a. A

[98] O.v.: multiphoner, scharf geräuschhafter Klang.

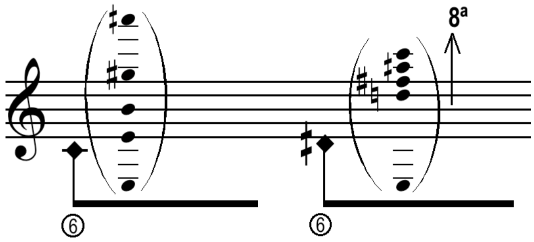

Figure 2.3. Examples of the notation of guitar multiphonics by Bartolozzi
Adapted from *Auser* (p. 3) by B. Bartolozzi, 1975, Milan: Suvini Zerboni (note: in the original score the beam's thickness decreases)

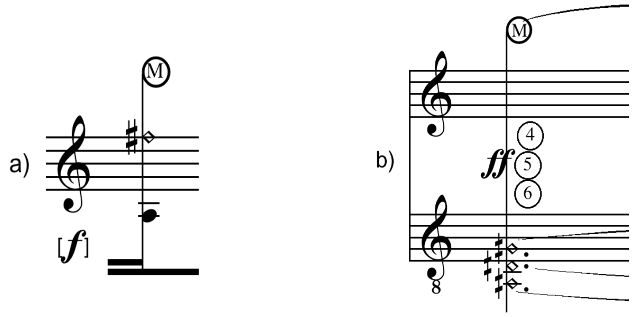

Figure 2.4. Examples of the notation of guitar multiphonics by Blondeau
Adapted from a) Non-lieu I (p. 9) by T. Blondeau, 2000, Paris: Jobert; b) *Pêle-mêle* (p. 51) by T. Blondeau, 2005, Paris: Jobert

similar notation can be found in Tel/f@x.comTM (Blondeau, 2005). Here, however, the pitches or the M are notated in an upper system, as in Fig. 2.4b. The notation of the string also differs from *Non-Lieu I*, since it is notated numerically, with the usual encircled number superimposed on the stem of the notational chord. The guitar is amplified, and the electronics of the piece consists of only pre-recorded sounds. Blondeau asks for two long multiphonics chords, each articulated alone and singly: one on strings 4 to 6 halfway between frets, for which a microtonal accidental is used (p. 51), and another on strings 5 and 6 at a fret (p. 54). It is also possible to find multiphonics in Blondeau's (1999) Petit non-lieu for solo guitar (with *scordatura*; 1998-1999), albeit implicitly. Most of this pedagogical piece is notated in tablature and asks for sounds resulting from the lightly touching of the strings at locations between frets III and XII, in simple rhythms but a fast tempo.[99] Ambrosini calls of "half positions"[100] the locations halfway between frets, and identifies these locations with

[99] According to guitarist Christelle Séry (2011, personal communication, November 17), Blondeau also requests multiphonics in *Lieu I* for ensemble (2007).

[100] O.v.: Metà posizione

"1/2" before the number of their space. The touch location is notated by using the ID of the location and a diamond-shaped note head with chromatic accidentals with arrows.

Contrary to Blondeau, the present author explicitly asks for the imitation of the sound of a bell in the score of *Cyrano-Szenen* for guitar (2004), a piece consisting of seven scenes inspired by the theatre piece *Cyrano de Bergerac* by Edmond Rostand. The sound, with which the piece begins, is articulated alone, and is long and repeated twice (Torres, 2004, I). This same gesture is also the beginning of the last scene (Torres, 2004, VIb), which is preceded by another long sound of multiphonics on string 6, with which the previous scene ends (Torres, 2004, VIa). The string is represented numerically and the fretboard location with a pitch symbol, an "M" is written above the staff, and four pitches are notated in parentheses, as depicted in Fig. 2.5. Fig. 2.6a depicts the other multiphonics request in this piece, which is also articulated with *tremolato* (for an explanation of the technique see subsection 3.2.1, Si amanece...). Fig. 2.6b depicts the single multiphonics request of another piece by the present author: *Le tombeau de Falla* for voice and guitar (2012), which sets to music four poems by García Lorca. The technique is requested after the singer recites the words "wounded by five swords", and the sound is left to ring (Torres, 2012, p. 3). The intention was word painting, as in the resulting sound the author can clearly perceive five pitches. However, due to the individuality of sound perception (see section 2.3.2), this intention is more of conceptual than of practical nature. The string is represented with a pitch symbol, and the fretboard location with a double notation, that is, a number and a pitch symbol, which is explained in a footnote.

Sam Hayden also uses an "M" above the staff in *AXE[S]* for solo guitar (1997), commissioned by guitarist Mats Scheidegger. The multiphonics requests are found towards the end of the piece, as well as in the end of it. When they are first used, the sounds are articulated alone and left to ring, and very rapidly follow and are followed by single notes or chords, except for the last three sounds that are long and played one after another (Hayden, 1997, pp. 25-27). In the end of the piece, the sounds are also articulated alone and left to ring, but are slowly alternated with long sounds of harmonics (Hayden, 1997,p. 34). As the composer explains, "fret position and string number are indicated – diamond note-head is position of touched note and small upper notes are the main sounding harmonics" (Hayden, 1997, Performance notes). Microtonal pitches are used for locations between frets – "fret position" refers then to the space between frets. Examples are provided in Fig. 2.7.

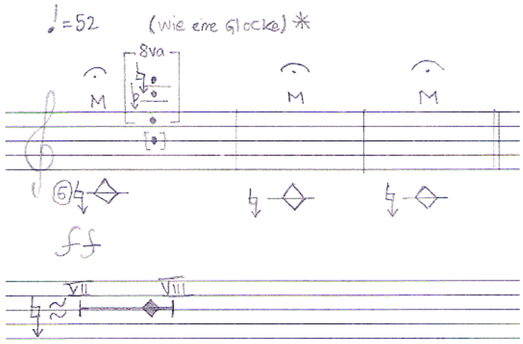

Figure 2.5. Score excerpt of Torres' *Cyrano-Szenen* showing the notation of guitar multiphonics

Reprinted from *Cyrano-Szenen* (scene I, bars 1-3), by R. Torres, 2004, Karlsruhe: the composer (note for the asterisk: "like a bell")

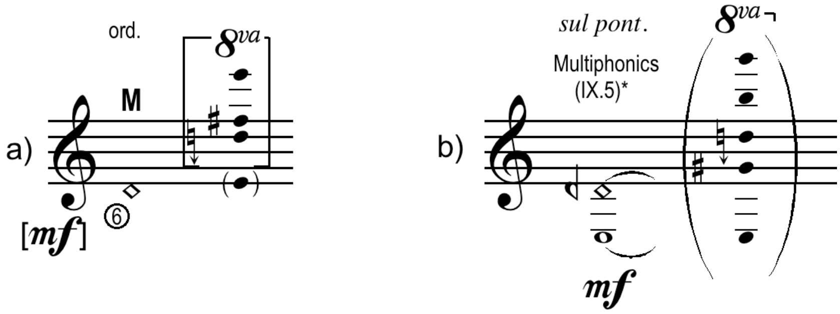

Figure 2.6. Examples of the notation of guitar multiphonics by Torres

Adapted from a) *Cyrano Szenen* (scene VI), by R. Torres, 2004, Karlsruhe: the composer; b) *Le tombeau de* Falla (p. 3), by R. Torres, 2012, Karlsruhe: the composer (note for the asterisk: "touch halfway between frets IX and X")

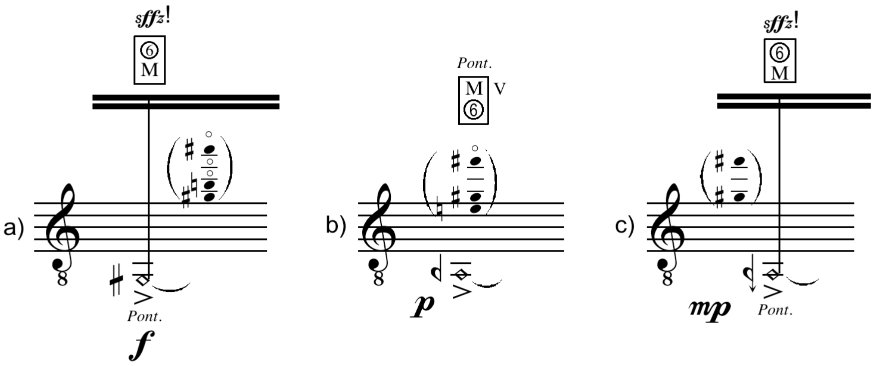

Figure 2.7. Examples of the notation of guitar multiphonics by Hayden

Adapted from *AXE(S)* (pp. 25 [a, c], 34 [b]), by S. Hayden, 1997, Composers Edition

The pieces for solo guitar *Nombres* (1986/87) by Fritz Voegelin, *etwas Klang von meiner Oberfäche* (1991) by Hans Ulrich Lehmann, and *Nach Innen* (1997) by Christoph Neidhöfer have in common the fact that they were composed in collaboration with, edited by, and dedicated to, guitarist Christoph Jäggin. The pieces by Lehmann and Voegelin were commissioned by the Swiss Association of Musicians, and consist of various movements. Voegelin (1987) scatters six different sounds of multiphonics along the six movements of the piece (pp. 3/6/7/11). Five of the sounds are played once and articulated alone; some are short whereas some are left to ring. In the piece by Lehman (1992), the (nine different) sounds are found only in the first of the eight movements pp. 2-3). This first movement consists almost exclusively of multiphonics, harmonics, and sounds of indefinite high pitch. The sounds of multiphonics short and articulated alone, and are mostly preceded or followed by another sound of their kind.[101] The piece by Neidhöfer (1997) features only two sounds of multiphonics: one sounds once, the other twice, and all left to ring alone (pp. 3/7). Moreover, string 6 is tuned in Eb and the pitch material of the piece is, according to Neidhöfer, developed from the intervals of the tuning (p. 8). Like Lehmann (introduction), Neidhöfer (p. 8), points to the low dynamics and subtle sonorous nuances as the main focus of the piece. Since Jäggin gave these three composers the reference of Schneider's book, their choice of sounds of multiphonics is almost exclusively limited to those notated in Schneider's chart. In the performance notes of the pieces by Lehmann (p. 15) and Neidhöfer (p. 8) Jäggin mentions that the notation of multiphonics is that of Schneider. However, this is only true for the result of the sounds, which he notates as an action. It is Jäggin's the “mph” above the staff[102] and the numeric notation of the fretboard location. When not at a fret, the fret number is either: (a) preceded by a minus sign, meaning to the left of the fret; (b) followed by a plus sign meaning to the right of the fret; (c) followed by an *o* (as superscript in Vögelin's piece), meaning at the middle of the space between that fret and the previous fret.[103] Fig. 2.8 exemplifies the notation used by Jäggin.

The multiphonics notation of Michael Reudenbach in *Schnitt & Fortsetzung* for flute, harp, guitar, piano, and timpano (2003) does not differ from that of Jäggin, with the exception that the “mph” above the staff is absent. This is because Jäggin supplied Reudenbach with Lehmann's performance instructions and Schneider's

[101] According to guitarist Christoph Jäggin (personal communication, March 25, 2013), Lehmann also requests multiphonics in *Um-Risse* for guitar and bariton saxophone (2004).

[102] In Lehman's piece “mph.” appears only in the first sound of the movement.

[103] These explanations are absent in Neidhöfer's piece. In Lehmann's piece there is a fourth possibility: a location between the 1st, or 2nd, and 3rd possibilities, for which both of these are separated by a slash.

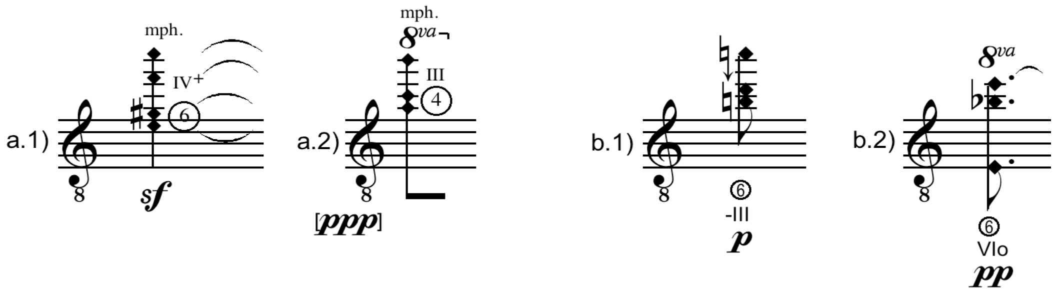

Figure 2.8. Examples of the notation of guitar multiphonics by Jäggin
Adapted from a) *Nombres* (pp. 3, 11), by F. Voegelin, 1987, Zürich: Hug; b) *etwas Klang von meiner Oberfläche* (p. 2), by H. U. Lehmann, 1992, Zürich: Hug

chart (M. Reudenbach, personal communication, November 17, 2013). Reudenbach (2003) mentions in the performance instructions that the multiphonics notation is that of Schneider, and provides a copy of his chart of multiphonics. He does not, however, explain the nomenclature of Jäggin for the fretboard locations. Reudenbach requests multiphonics four times during this quiet piece, in a total of three different sounds, all left to ring (pp. 1, 2 ,5 ,6). Two sounds are articulated with short piano and harp sounds, and the other sound is articulated alone.

In Flageoletts for guitar (2014) and in Wavelets for flute, guitar and cello (2014), Willian Lentz has also notated the result as an action, using also diamond-shaped note heads. He wrote "Multif." above the staff, and notated the touch locations between frets numerically and below the staff, using the number of the space and a fraction. The denominator of this fraction corresponds to the number of parts in which the space is subdivided, and the numerator corresponds to the part at which the touching takes place. Six different sounds of multiphonics are requested towards the end of Flageoletts (Lentz, 2014a, pp. 6, 7); three of them are single occurrences and are left to ring, and the other three occur multiple times, and are either left to ring or are grace notes to other sounds of multiphonics; Some requests present the particularity of being articulated in legato (departing from the open-string sound) – in this case the note-heads of the pitches are crosses –, or of being played *staccato*. In *Wavelets,* Lentz (2014b) made use of only two sounds, which are to be mostly repeated as a pedal tone in certain moments along the piece (pp. 1-4).

A separate upper staff has been used by some composers to notate the result of multiphonics. This puts in evidence an interest for the harmonic features of the sounds, which has been confirmed by Rafael Nassif and Roman Pfeifer. For Pfeifer, the sounds of multiphonics in Die illegale Ausübung der Astronomie I for solo guitar (2002) "are part of the harmony, and often even point of departure for the harmonic development" (personal communication, May 10, 2011).[104] His piece consists almost exclusively of sounds of harmonics and multiphonics played with simple rhythms in a slow tempo. The sounds of multiphonics are all played on string 6 and articulated alone. Both string and fretboard location are notated with pitch symbols, which have microtonal accidentals at locations between frets, as Fig. 2.9b. The performance instructions contain a list of the sounds of harmonics and multiphonics used throughout the piece, showing the notation for their fretboard location and the result (Pfeifer, 2002, Griff und Klang). Pfeifer used, however, only one staff while composing, notating the result as an action, and using numbers for the string and fretboard location, as depicted in Fig. 2.9a. When the fretboard location is not at a fret, he added a superscript to the fret number, showing a plus sign, a minus sign, or an arrow (the latter meaning even further away from the fret). Pfeifer changed this notation because, for the guitarist with whom he worked with, it "ended up in being too complicated to learn, although it looks visually simpler" (personal communication, May 10, 2011).[105] This might be related to the fact that, as in the notation of Schneider (and Jäggin), the resulting sounds are notated with diamond-shaped note-heads, which usually indicate where to touch (Schneider's book was, however, not of Pfeifer's knowledge [R. Pfeifer, personal communication, Dec. 13, 2013]).

In *silhuetas de uma dança imaginária,* for guitar quartet (2009-10), commissioned by the guitar quartet *Corda Nova*, Nassif chose the sounds "not only for their harmony but also for their colour" (R. Nassif, personal communication, October 31, 2011).[106] He advises the guitarists that they "should practice enough to produce in a balanced way the sound amalgam notated" (Nassif, 2010, directions for study and performance: 2). Per guitar and throughout the piece, there are six different *sound amalgams* articulated alone or with sounds of another guitar, and always a part of a quartet gesture, sounding rarely alone. They are played on strings 4, 5, or 6 at the same two locations between fret XIX and the saddle, respectively "slightly below the node of the seventh partial (harmonic) and below the node of the fourth partial (harmonic)"; the sounds "can be played at the fretboard as well" (at their mirror location to fret XII) (Nassif, 2010, directions for study and performance: 2). The fretboard locations are, however, not notated in the score. Nassif chose the fretboard locations between fret XIX and the saddle for the score, because, when

[104] O.v.: Die Multiphonics sind Teil der Harmonik und oft sogar Ausgangspunkt für Harmonische Entwicklung.

[105] O.v.: Die erste [Version] hat sich zum Lernen als umständlich erwiesen, obwohl sie visuell etwas einfacher aussieht.

[106] O.v.: Os multifônicos foram sim procurados com interesses harmônicos, mas também tímbricos.

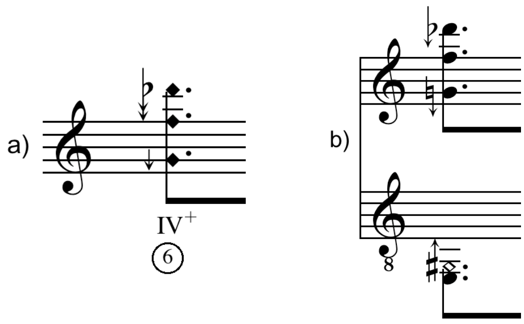

Figure 2.9. Examples of the notation of guitar multiphonics by Pfeifer (guit. with *scordatura*) (a) while composing; (b) after working with a guitarist

Adapted from a) *Die illegale Ausübung der Astronomie* (manuscript, bar 4), by R. Pfeifer, 2002, Essen: the composer; b) *Die illegale Ausübung der Astronomie* (typescript, bar 4), by R. Pfeifer, 2002, Essen: the composer.

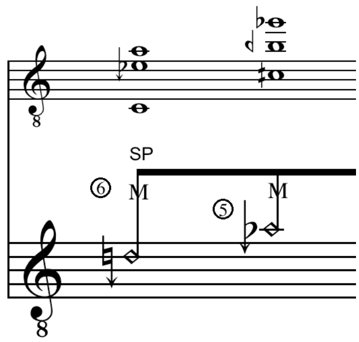

Figure 2.10. Examples of the notation of guitar multiphonics by Nassif (guit. with *scordatura*)

Adapted from *silhuetas de uma dança imaginária* (p. 1, guitar 4), by R. Nassif, 2010, Stuttgart: the composer

trying things out on the guitar,[107] it became easy for him to produce the sounds that way (R. Nassif, personal communication, November 12, 2011). He notated the string numerically, the fretboard location with a pitch symbol, which has a microtonal accidental at locations between frets, and superimposed an “M” on the note stem, as depicted in Fig. 2.10. The composer stresses that amplification should be used when the acoustic conditions are not favourable to a guitar performance:

> Unless the work is played on a small hall or in one where the guitar is favored, a subtle amplification may be necessary as the timbres are in general very subtle and have limitations concerning dynamics; in this case, four loudspeakers should be placed discretely beside their respective musicians. (Nassif, 2010, Directions for study and performance, p. 1)

[107] Nassif had one year of education in guitar as child before turning to the piano *R. Nassif, personal communication, October 31, 2011).

Another composer who used of a separate upper staff to notate the result was Helmut Lachenmann in Salut für Caudwell for two guitars (1977). However, he did not use this staff throughout the score but only for specific sounds; and he sometimes used parentheses instead. Moreover, he notated the actions of each hand in separate staves, using tablature for the right hand. Guitar 1 is to play three of the four sounds of multiphonics of the piece (Lachenmann, 1985, p. 3, bar 49; p. 4, bar 78;[108] p. 10, bar 162), and guitar 2 (tuned a half-tone lower) is to play the fourth and last of those sounds (Lachenmann, 1985, p. 15, bar 266). Except for this last case, in which the result is notated as an action, the fretboard locations are notated with pitch symbols, which have microtonal accidentals at locations between frets, and the string is notated in tablature with a squared note head.

In various pieces, the player is free to choose the touch locations. In Clemens Gadenstätter's *variationen und alte themen* for trombone, guitar, cello and double bass (1996) “the exact touch locations may be freely chosen but should always give rise to a sound as characteristic as possible” (Gadenstätter as quoted in Josel & Tsao, 2014, p. 124, footnote 94).[109] Diamond-shaped note heads connected to stems with a superimposed M are therefore located above the staff. The sounds are articulated with cello and double bass multiphonics.[110] In *Untitled Composition in Three Sections* for flute and guitar (1975), William Bland calls the sounds *complex harmonic partials.* These are played with a fast rhythm and left to ring, accompany a flute melody, and are notated with a cross-shaped note head (Schneider, 1985, p. 136).[111] The piece by Horațiu Rădulescu, *Subconscious wave* Op. 58 for guitar (with scordatura) and “taped digital sound” (1985), is the earliest piece of this review in which the terms *multiphonic* and *multiphonics* can be found. The former is used as an adjective (“multiphonic sound”), to explain what the “M” above the timeline of events means, and also how the sound is obtained: the numerically notated strings are touched “inbetween the points along the string where ... natural harmonics are obtained. e.g. inbetween the 4° & 5° or 3° & 4° or on intervals as the minor 10th or tritonus in relation to the open string” (Rădulescu, 1985, performance instructions, p. 2). The noun “multiphonics” appears when the sounds are first requested

[108] Here, the notated result does not correspond to the notated touch location.

[109] O.v.: "Die genauen Berührungsstellen sind frei wählbar, sollten aber immer ein möglichst charakteristisches Klangbild erzeugen"

[110] According to the guitarist Jürgen Ruck (personal communication, April 14, 2015), Gadenstätter also requests multiphonics in *4 Szenen nach Francisco Goya* for guitar and voice in one person (2004/2006).

[111] According to Schneider, Bland also requests multiphonics in *An Impression by Crumb* for guitar and ensemble (1975).

(Rădulescu, 1985, 5'20''). Here they are played and left to vibrate, firstly simultaneously on two variable strings, and then on all strings. In a second moment, they are played with bow on string 6. Rădulescu (1985) leaves open the possibility of amplifying the guitar "with 2 condenser microphones (not contact!) & equal thus the dynamic of the taped digital sound", and of using metal strings to better achieve "the high harmonics & the bowing techniques" (performance instructions, p. 2). In *Mich.Stille* for guitar quartet and tape (2000) by Helmut Oehring – commissioned by the guitar quartet *Aleph* – and in *Voces de profundis* for solo guitar (1984; with string 6 in D) by Štěpán Rak the multiphonics requests are implicit. Throughout *Mich.Stille*, in which the tape part consists of a quite explicit "coughing, breathless female voice" (Künzig, 2012, p. 13), Oehring (2000) asks for "dirty harmonics", which he explains to be a four to six-stringed "harmonics-*barré* between frets or at locations that respond less well, as for example at frets III, IV, VI, X" and that the players should "avoid the usual touch locations (at V/VII/XII/XIX/ etc.)" (Anmerkungen).[112] The sounds are always articulated with sounds of other guitars, and are notated with vertically-oriented rectangular note heads. In *Voces de Profundis*, which was "inspired by the film Psycho" (Rak, 1985, p. 2), Rak (1984) asks for "harmonics ad. lib. at the 6th and other frets excluding usual positions (i.e. 5th, 7th, 9th, 12th)" (p. 1). The sounds are played alternately on strings 5 and 6 eight times in a row, and articulated alone and left to ring; they are notated below the staff with squared note heads (p. 4).

By letting the player choose the touch locations freely, the composers are then not interested in the content of the sounds. This is also the case of Uroš Rojko in *Passing away on two strings* for solo guitar (1984). Two sections of the piece consist of a slow crochet-gliding of touching fingers along strings 5 and 6 which are always plucked near the bridge (Rojko, 1984, pp. 1, 3). The fingers are to leave the string immediately after plucking except at two short *pianississimo* moments in which a "short-sounded harm[onic]" should be obtained (Rojko, 1984, performance instructions). The gliding halts at three locations at which it is possible to play harmonics (or multiphonics with one emphasised pitch). Apart from a few exceptions, Rojko notated only that kind of locations, using the symbol of the fretboard location and a pitch. The string numbers are notated at the beginning of the glide. When the gesture appears for the second time, he notated a location between frets with a microtonal accidental. Rojko, who "played and tried out everything" himself (Rüdiger & Rojko, 1995, p. 27), is interested in the (implicitly-requested) sounds of

[112] In this piece, guitar 1 is a terz guitar, string 6 is in D in guitar 2 and in Eb in guitar 3, and guitar 4 is a bass guitar.

multiphonics as transitions between sounds of harmonics:

> What is nice is how a tone (overtone) progressively turns into another one—sometimes through a whole palette of (multi)sounds [*Mehrklänge* is the word for multiphonics in German]. ... Multiphonics are ... the main theme of the piece—the TURNING thus of one overtone INTO another one. (U. Rojko, personal communication, December 4, 2011)[113]

In *Sette studi* for solo guitar (1990), Maurizio Pisati (1990) exploited the "perceptive limits" of each sound (Introduction). He adverts then that "the possible use of amplification should therefore be considered as a means of underlining and *enhancing the differences* rather than bringing everything up to a greater and uniform audibility" (Introduction). The term multiphonics is not to be found in this piece. Instead, Pisati mentions that "harmonics on 'false' positions" are a sort of sonority of the piece, and stresses that the fingerings he uses "are not only suggestions but should be considered essential to the faithful interpretation of the *Seven Studies*" (Introduction). In Study 2, the sounds are short and articulated alone, mostly at the beginning of the study (Pisati, 1990, pp. 5-6); in Study 5 an arpeggio of a chord of multiphonics on strings 4 to 6 is repeated eight times (Pisati, 1990, pp. 17-20). Pisati notated multiphonics with a number for the string and a pitch symbol for the fretboard location, using microtonal accidentals when the later is not at frets. He does not explain these accidentals, but the quarter-tone accidentals of the touch locations of a different type of sound correspond to "distances corresponding the hypothetical quarter-tones" (Pisati, 1990, performance instructions, symbol 12). It is presumed that this also applies to the touch locations of multiphonics. Resulting pitches are provided in parentheses and are notated with squared white note-heads, as in Fig. 2.11a-c. The multiphonics chord depicted in Fig. 2.11d is an implicit multiphonics request, as he did not notate pitches.

Also implicit are some of Lin-Ni Liao's multiphonics requests. The third movement of her *p.53* for solo guitar (2008) consists of only harmonics and multiphonics played exclusively at frets (Liao, 2008a, III). The sounds are articulated alone, mostly in quavers, and left to ring. A double notation is used for both string and fretboard location, and pitches are sometimes attached in parentheses to the fingering chord. A short section of Liao's *Imamusi* for viola, guitar, baritone saxophone and piano (2008) is similar to the third movement of *p.53,* but only one pitch is given in parentheses, even when only multiphonics can be played, possibly

[113] O.v.: Das schöne dabei ist, wie ein Ton (Oberton) in den anderen allmählig übergeht - manschmal durch eine ganze Pallette von anderen (Mehr)klängen. … Mehrklänge sind … das Hauptthema des Stückes - also ÜBERGEHEN von einen Oberton zu dem nächsten.

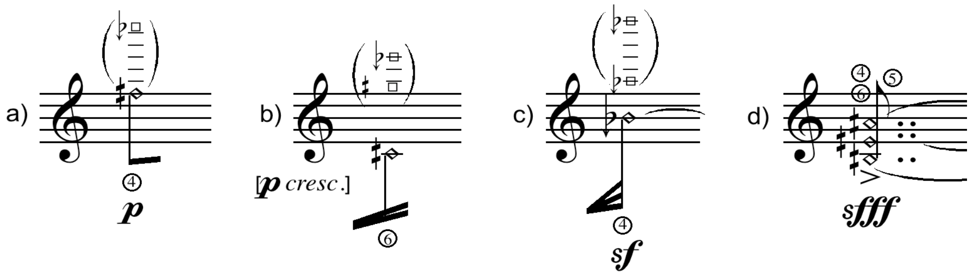

Figure 2.11. Examples of the notation of guitar multiphonics by Pisati
Adapted from *Sette studi* (pp. 5 [a], 17 [b]), by M. Pisati, 1990, Milan: Ricordi

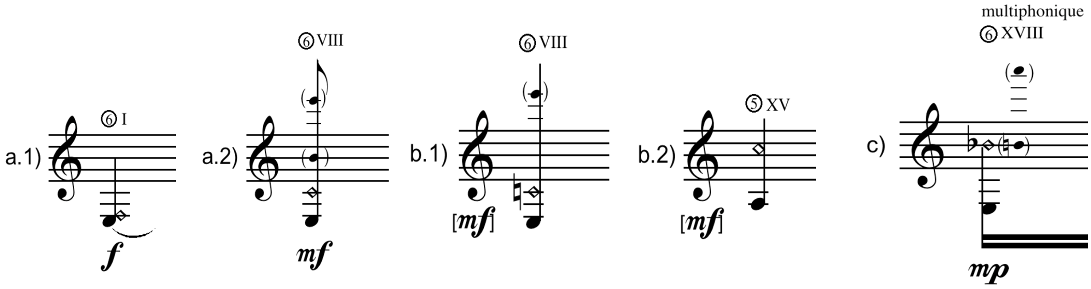

Figure 2.12. Examples of the notation of guitar multiphonics by Liao
a) Adapted from *p.* 53 (III), by L.-N. Liao, 2008, Paris: the composer; b) *Imamusi* (p. 8), by L.-N. Liao, 2008, Paris: the composer; c) *Le train de la vie I – Doris* (p. 4), by L.-N. Liao, 2010, Paris: the composer

because the pitches are to be emphasised (Liao, 2008b, p. 8). For the single sound of multiphonics of *Le train de la vie I – Doris* for guitar and tape (2010), Liao used a similar notation with the word “multiphonique” (Liao, 2010, p. 4). Examples from three pieces by Liao can be found in Fig 2.12.

According to Vishnick (2014, p. 240), it is also possible to find multiphonics in *Tempo Mental Rap* for guitar (2005) by Michael Edgerton, who “used a conventional notehead with two small zeros stacked above”; *Bento Box* for alto flute, guitar and vibraphone (2007) by Joseph Pereira, who charted resulting pitches “as a block chord on a five-line stave”; and *Mouvement apparent* for guitar (1998) by Philippe Durville, who notated the touch location and one resulting pitch in parentheses. When composers always and exclusively notate one pitch whichever the touch location, and they do not make any reference to multiphonics, their intention is often harmonics. Some composers are not aware that this is not possible at some locations. This is, however, not the case of Michael Pisaro (1996, p. 1) who advises the player: “It should be noted that, especially with the case of higher harmonics, more than one tone is likely to sound, due to the fact that these harmonics are rarely to be isolated. These other tones have not been notated.” Pisaro notated the string numerically and used graphic notation for the fretboard location, as in Fig. 2.13. Higher sounds of harmonics are, however, possible to isolate by touching the string at two adjacent nodes of the fundamental of the sound.

Discussion

In most reviewed pieces asking for specific sounds, an explanation of the notation of locations that are not situated at frets is either not provided or vague. When microtonal pitches are used to notate touch locations at which the string would be stopped were it not for the presence of (semitonic) frets, an explanation should be provided especially when symbols other than those for quarter-tones are used, as a generalised symbol-system exists mainly for the latter. When the accidentals system is not explained, or the explanation of the numerical notation is not precise, and (1) the result is not notated, there is a certain degree of freedom in situating the location; (2) the result is notated, the greater the number of pitches, the more exact the place of the location. When the location is exact (as is the case of some of the locations suggested in the scientific literature), it might not be not easy to come up with orientation references for its visual situation. As Josel and Tsao (2014) stress, “precisely locating each multiphonic demands practice” (p. 119). Similarly, Vishnick (2014) remarks that “consistent work on left-hand accuracy … is essential” (p. 241). In fact, Pfeifer sensed during the performance of *Die illegale Ausübung der Astronomie* “the millimetre work it means for the guitarist” (R. Pfeiffer, personal communication, May 6, 2011),[114] whereas for the players of the premiere of Nassif's *silhuetas de uma dança imaginária*, “the exact point of the string where the multiphonics should be found was initially not clear” (R. Nassif, personal communication, October 31, 2011).[115] The guitarist is thus compelled to memorise the location by instinct, but microtonally, a situation to which players of fretless instruments are more used. When there are poor orientation references for the visual situation of a location, there is then a greater degree of uncertainty in where exactly to play. This should lower the reproducibility of the sounds, (i.e., their degree of similarity), which is problematic in live performance when specific sounds are intended. For which, in this situation, the locations should be easy to visually situate.

A lack of variation in the attack and in the decay of the sounds of multiphonics was also verified in the reviewed pieces. These kinds of variation are especially important in pieces centred in this kind of sounds, otherwise these may become monotonous. Variation in the attack of the sounds could only be found in one of the

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[114] O.v.: Man spürt welche Milimeterarbeit das für den Spieler ist.

[115] O.v.: De início nao [foi] claro para os músicos o ponto exato da corda onde os multifônicos seriam encontrados.

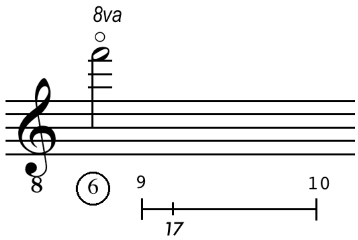

Figure 2.13: Examples of the notation of guitar harmonics by Pisaro
In the graphic notation "the upper numbers refer to frets, counting from the first fret above the nut. The [position of the] numbers below indicate the approximate (within a few millimetres) location of the harmonic [which has that number]" (Pisaro, 1996, p. 1).
Adapted from *Mind is moving (I)* (p. A/4), by M. Pisaro, 1996, Haan: Wandelweiser.

pieces by Lentz (2014a), who asks for some sounds to be played in *legato;* and in one of the pieces by the present author (Torres, 2004), in which a sound is also articulated with *tremolato*. Variation in the form of decay of the sounds could only be found in the same piece by Lentz, in which some sounds are played *staccato,* and in the piece by Rojko (1984), in which the sounds are progressively damped by continuing the touching. Both forms of variation can be found in the piece by Rădulescu (1985), since he asks for the sounds to be also played with bow.

The composers did not explore the amplification of the sounds of multiphonics,[116] nor did the scientific authors. This is surprising considering that the relative loudness of some of their main components may be quite soft. In the only piece scored for amplified guitar (Blondeau, 2005), amplification is most certainly used to make the guitar at all audible among the other instruments of the ensemble. Similarly, Rădulescu mentions the possibility of amplifying the guitar to obtain a better mixture with the tape (see 2.3.1, Artistic literature). The reason for Pfeifer not wanting to use amplification (see section 2.1.3, To amplify or not to amplify) is that, when he tested it, the microphone mainly picked-up the thud of the attack (R. Pfeifer, personal communication, May 6, 2011). This, however, may have been, on the one hand, due to lack of experience of the player with multiphonics, because it is possible to minimise the level of the thud; and, on the other hand, due to a placement of the microphone too close to the sound hole. Nassif and Rojko resort to amplification when the acoustical conditions are not favourable. Nassif stresses, however, that he dislikes this situation (R. Nassif, personal communication, November 12, 2011). This is perhaps because the quietness of the sounds "becomes

[116] When using tape, the instruments are often amplified. It cannot be excluded then the possibility that Liao (2010), who, contrary to Rădulescu (1985), does not allude to amplification, took it into account in her compositional approach.

a colossus, a monster" with conventional amplification, as Rojko experienced in the premiere of *Passing away on two strings*, having used light amplification in following performances (U. Rojko, personal communication, January 4, 2012).[117] In both cases, it appears that amplification was used only with the intention of enhancing the content of the sounds that is perceived without amplification.

2.3.2 Acoustics and psychoacoustics

Sound production

On the guitar, the technique of multiphonics, like that of harmonics, consists in damping out some of the vibrational modes (v.ms.) of the string (i.e., suppressing the v.ms. at least to the point at which their strength is negligible), by lightly touching it at certain locations during or after its excitation (or both). Touching the string absorbs its vibrational energy (Kubilay, Vesikkala, Pàmies-Vilà, Kuusi & Välimäki, 2015, p. 7). Not all v.ms. might however be damped because some may have a node at the touch location, and v.ms. are (ideally) not damped at their nodes (Taylor, 1978, p. 30) (Appendix A contains a representation of the first 39 v.ms. of a string). The amount of damping suffered by a vibrational mode (v.m.) when the string is touched depends on its loop displacement at the touch location, the touch pressure, and realistically, the malleability and width of the toucher. The loop displacement at the location depends on (a) its degree of excitation, (b) its loop length and (c) the distance from the location of its nearest node. The degree of excitation of a v.m. depends on: (a.1) its excitation strength – this is inversely proportional to the square of the v.m.'s mode number (Benade, 1990, p. 100); (a.2) the excitation location – the closer the location is to a node, the less excited the v.m. (Schneider, 1985, pp. 17-18); and, realistically, (a.3) the width of the exciter – the v.m. is not excited when its node is also covered by the exciter (Taylor, 1978, pp. 25-26). In regard to the loop length and the distance from the location of its nearest node, it is equivalent to speak of *relative loop displacement* (r.l.d.) at the location. That is, the displacement of its loop at the location relatively to its displacement at the anti-node (the point of maximum displacement). The greater the degree of excitation and the r.l.d., the greater the energy loss. This is also true for an increase of the touch pressure and the malleability and width of the toucher. An increase of the touch pressure implies, moreover, a larger surface of a soft toucher, which may damp out the higher v.ms. by covering, or increasing the partial cover their (smaller) loops.

[117]O.v.: Dann ist das Stück ein Riese, ein Ungehäuer.

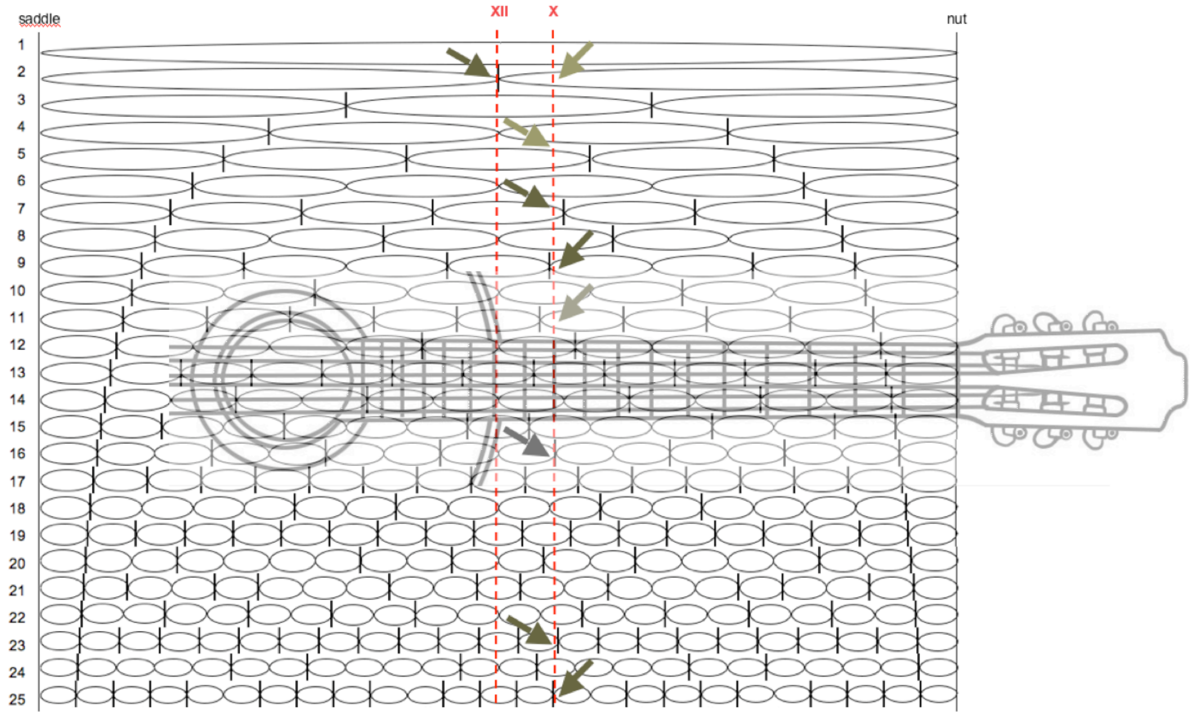

Figure 2.14. Juxtaposition of the representation of the first 25 vibrational modes of a string Differences in the excitation strengths of the vibrational modes are not accounted for. The main nodes of each vibrational mode are marked with a small vertical line. The dashed lines symbolise the touching of the string at frets X and XII. The arrows point to the vibrational modes with main nodes near the touch locations.

What distinguishes harmonics from multiphonics is that with harmonics the filtering of the v.ms. is systematic with respect to mode number – every nth v.m. is not damped out – whereas with multiphonics it is not. The mode numbers of the v.ms. that are filtered in harmonics have all then a least common multiple other than 1, and they all share a same node at, or in the vicinity of, the touch location. This is what (usually) takes place when touching at fret XII, as exemplified in Fig. 2.14: fret XII (the middle of the string) is at a node of v.m. 2 and its multiples – thus at a *main node* of v.m. 2, that is, v.m. 2 is the lowest v.m. sharing the node – and at an antinode of all other v.ms. The odd-numbered v.ms. are therefore damped out and the even-numbered v.ms. are not. Although the v.ms. of the latter kind that have a node at the excitation location are hardly excited, this non-excitation is systematic with respect to mode number, for which what was stated above remains true. The lesser degree of excitation of the higher v.ms. may not be systematic but does not play a major role.

The other touch location in Fig. 2.14, fret X, presents a case of multiphonics.

V.m. 16 and its multiples[118] are not damped out because the touching takes place at a node of theirs. Very near the location there are, however, other nodes. These are main nodes of v.ms. 7, 9, 23, and 25. These v.ms. and their multiples, or at least v.ms. 7 and 9, will not be damped out, because, as Schneider (1985) stresses, “the stronger lower harmonics will sound even if the node-producing finger is not touching exactly the right point on the string” (p. 136). In other words, the lower v.ms. have higher excitation strengths, thus their strength is less affected than that of higher v.ms. when they are damped by a similar amount. Depending on the touch pressure, v.ms. 2 and 5 (the lowest v.ms. after v.ms. 7 and 9 with nodes close to fret X; see also Fig. 2.15) might not be damped out. Attempting a definition, *the technique of multiphonics is a technique that, by lightly touching the string, with respect to mode number unsystematically damps out some of its v.ms., giving rise to a sound in which the frequencies of neighbouring components are not all equally spaced.*

Despite not being possible to play harmonics at locations like fret X, there are locations, at which both techniques are possible. Moreover, it is never impossible to play multiphonics because the lower v.ms., especially v.m. 1, are hardly damped out if an extremely light touch pressure is used.[119] There are then three kinds of touch locations on a string:

A) those at which, the technique of multiphonics is only possible when the string is touched with an extremely light pressure, otherwise the technique of harmonics is played;
B) those at which, at least right after the attack, both the techniques of harmonics and multiphonics are possible, depending the execution of one or another on the (stronger) touch pressure.
C) those at which, right after the attack, the technique of multiphonics is the only feasible because it is not possible to systematically damp out v.ms.

It is then possible to continuously play multiphonics along the string when the touch pressure is extremely light. Otherwise, the feasibility of the technique, that is, the degree of achievement of mode-number unsystematism in the filtering of v.ms.,[120] may vary.

Once the sounds are produced, the string may be: (a) left to vibrate freely, by stopping the touching, or constrainedly, by continuing the touching; (b) rapidly newly

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[118] Possible only v.m. 32, as "string stiffness tends to set a limit, somewhere between twenty and forty, to the number of effective modes of a guitar string." (Taylor, 1978, p. 22).

[119] At locations near the nut or the saddle it is not possible to damp it out.

[120] The Institute of Electrical and Electronics Engineers (1990, p. 87) defines feasibility as “the degree to which the requirements, design, or plans for a system or component can be implemented under existing constraints.”

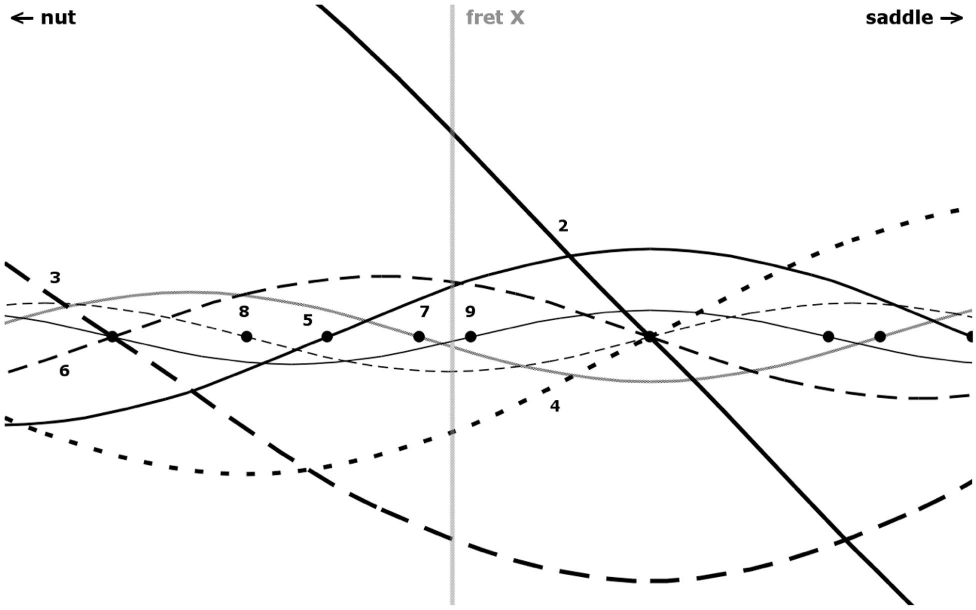


Figure 2.15. Superimposition of the representation of vibrational modes 2-9 of a string between 30% and 60% of the string's length

In opposition to Fig. 2.14, the figure is oriented from the viewpoint of the player.

excited once, various times or repeatedly. In case the string is left to vibrate freely by stopping the touching, the longer the finger remains on the string, the faster the decay of the v.ms. because there is an increase of their damping. This is, once again, more significant for v.ms. with larger r.l.ds. and higher excitation strengths. Realistically, it is also more significant for v.ms. with smaller loops, due to the fact that a surface touches the string. Therefore, the reliability of the sounds of multiphonics, that is, the degree of maintenance of the filtered partials during a certain period of time,[121] should, like the feasibility of the technique, vary with the touch location. When the string is left to vibrate constrainedly by continuing the touching, a transition from multiphonics to harmonics takes place not only at locations of kind B but also at some locations of kind C, because the v.ms. with larger r.l.ds. or smaller loops are progressively damped out. A transition from harmonics to multiphonics at locations of kind B is not possible because the v.ms. that give rise to the sound of multiphonics are all initially damped out. It is however possible to make a transition between a sound of harmonics and a sound of multiphonics at different locations, or between two sounds of multiphonics. This, however, is limited because many v.ms. are damped out when the string is touched

[121] Institute of Electrical and Electronics Engineers (1990, 170) defines reliability as "the ability of a system or component to function under stated conditions for a specified period of time."

for the first time. It is also limited to play multiphonics departing from the open-string sound because some of the higher v.ms. may have totally decayed when touching occurs. Nevertheless, a transition can be abrupt or progressive, depending on the touch pressure. The lighter this is, the longer the touch duration has to be for the desired sound to be attained. In a transition to a sound of harmonics, if the v.ms. that give rise to the desired sound have smaller loops, this is, in fact, only practicable progressively (i.e., touching very lightly), otherwise those v.ms. are damped out, given that a higher pressure implies a larger touching surface. When the string is rapidly repeatedly excited, a transition from harmonics to multiphonics is possible by decreasing the touch pressure, but only at locations of kind B because these are the only locations at which harmonics is possible right after the attack. The slower the decrease of the touch pressure, the longer the transition takes.

The technique of multiphonics works much better on wound strings. The winding allows a decrease of thickness by increasing the linear density "without adding much stiffness" (Benade, 1990, p. 344). They therefore offer less resistance to bending, which allows the higher modes to vibrate easier than in the non-wounded strings.[122] To the knowledge of the author, a study of the behaviour of the plucked string in multiphonics lacks in literature. Artificial multiphonics is also possible (i.e., stopping the string at a certain fret, and touching it either with the same hand or with the hand that excites the string). This is, however, a less successful variant on the guitar, as there is a much lesser degree of freedom of either the excitation location or the touch location, depending on with which hand the touching takes place.

Sound radiation

The sound radiated by the string is very weak when compared with that radiated by the body. This is because, firstly, the string "has a relatively small surface area, and therefore cannot produce a large disturbance of the air. Secondly, any compression wave coming from one side of the string is effectively cancelled by a wave of rarefaction from the other" (Taylor, 1978, p. 33),[123] due to diffraction, since the string's diameter is very small compared with the wavelength of the vibration.

[122] According to Tyler & Sparks (2002), wound bass strings grew popular in the second half of the eighteenth century, as they allowed "more powerful bass notes, without the need for octave stringing" (p. 258). As these authors point out, they are thus bound up with the gradual change to single stringing, which started in Spain around 1800 (p. 236), after the six-course guitar had superseded the five-course instrument (pp. 195/212). Other relevant construction innovations, both from the nineteenth-century and contributing to boosting the sound, are the addition of the saddle, which transmits more efficiently the vibrations of the string to the soundboard (Russel, 2003, p. 157) and the increase of the size of the body (Miteran, 1997, p. 214).

[123] This is called *acoustic short circuit* (Bader, 2005, p. 33).

The smaller this wavelength, the more successful the string radiation. For which, only the higher partials are, in fact, radiated by the string (Meinel, 1991, pp. 58, 62). In turn, the guitar body radiates the entire sound spectrum of the guitar, because it has a large enough surface to move a sufficient amount of air, and to disallow a movement of the air molecules "either sideways or into the region of negative pressure underneath the top plate. Thus, the only direction in which the stimulated air molecules can move is directly away from the instrument." (Bader, 2005, p. 34).

Each part of the body is mainly responsible for a frequency range of the radiated spectrum. The enclosed air is responsible for the lower frequencies and radiates the most intensively (through the sound hole); the back plate and the ribs are responsible for the middle-range frequencies; and the soundboard and the neck – the latter with the least intense radiation – are responsible for the higher frequencies (Bader, 2005, pp. 57, 153, 168-9; Rossing & Caldersmith, 2010, p. 20). Despite being a poorer radiator than the air, the soundboard is psychoacoustically the loudest part, since it radiates in a frequency region in which the ear is more sensitive (Bader, 2005, p. 57). It also plays an important role in transmitting the vibration of the strings to the other parts of the guitar (Bader, 2005, p. 54).

Certain frequencies are enhanced by each body part's resonances (Benade, 1990, p. 318), which depend on the design and construction characteristics of the instrument (Rossing & Caldersmith, 2010, pp. 33-35).[124] The resonances of the soundboard are especially significant. As Taylor (1978) stresses, "any partial of a note which happens to lie close to a soundboard resonance will be emphasized" (p. 36). Therefore, the strength of the partials, which may vary during the decay of the sound (Josel & Tsao, 2014, p. 212) depends also on the execution factors that play a role in the degree of excitation of the v.ms. of the soundboard. These are:

- The string deformation on release, which depends on the manner in which the string is released (Taylor, 1978, pp. 26-27; Meyer, 1985, p. 15; Carral, 2010). The more gradual the release of the string, the lesser the excitation of the higher v.ms. of the soundboard. This is because a gradual release (e.g., by sliding the nail obliquely across the string) smoothens the edges of the waveform of the impulses that travel along the string and exert force on the bridge. This effect is enhanced by a soft or round plucker (Taylor, 1978, p. 26-27).
- The direction and magnitude of the string's displacement on release (Taylor,

[124] Measurements by Meyer (1985) on a "good Spanish guitar" (p. 37) show strong peaks around 100, and 200 Hz, as well as peaks of relevant intensity around 450, 550, 650, 900, 1100, 1200, 1400 and 1800 Hz (p. 38).

1978, pp. 38-41, 48-51; Carral, 2010). The direction component that is perpendicular to the soundboard – which is greater in a rest stroke than in a free stroke – drives the soundboard directly, which favours the excitation of its lower v.ms. The parallel component drives the soundboard indirectly by producing “a very slight rocking of the bridge” (Taylor, 1978, p. 38), which may become significant at higher frequencies (Rossing & Caldersmith, 2010, p. 20). The greater the displacement of the string, the stronger the excitation of the v.ms. This is, however, not possible in all directions, as there is “a limit to the amplitude of the perpendicular component which may be imparted without causing fret-rattle” (Taylor, 1978, p. 50).[125] Hard pluckers favour the string displacements (Carral, 2010).

Sound perception

The kind of spectrum of the sounds of multiphonics facilitates the perception of multiple pitches. According to Benade (1990):

> Our nervous system processes complex sounds coming to it by seeking out whatever subsets of almost harmonically related components it can find. Each of these subsets then has a “best fitting” collection of true harmonics selected for it in the processor, and pitch is assigned on the basis of the repetition rate of these fitted components. … The better the heard components agree among themselves regarding the degree of harmonicity in their relationships, the quicker and more certain we are in our pitch decisions regarding them. (p. 68)

The unsystematic filtering in multiphonics thus facilitates our nervous system in the grouping of the resulting sound's partials into subsets of fundamentals, hereafter *main partials*, and their overtones; these subsets are then assigned to different pitches.[126] Due to the individuality of sound perception (Schneider & Wengenroth, 2009), the sounds of multiphonics tend perhaps to be recognised by spectral listeners as multiple-pitched, whereas holistic listeners might consider one of the fundamentals as the pitch of the sound. The “spectral pitch mechanism” needs, however, longer to build-up than the “central pitch mechanism” (Roederer, 1995, pp. 149-150).

The spectrum of the sounds may also lead to the perception of bell-like

[125] Experiments by Richardson requested by Taylor (1978) show that, at frequencies below 1500 Hz, "considerable higher sound intensities are produced by perpendicular than by parallel plucking." Above that frequency value "there seems to be no consistent difference between the two directions of plucking" (pp. 40-41).

[126] The sounds of multiphonics are “ultimately the open-string sound disguised”, as Devoto (2011, p. 69) points out.

sounds. This is due to the inharmonicity of the higher partials, that is, to their frequencies not being integer multiples of a fundamental frequency.[127] This phenomenon, for which the string's stiffness is responsible (Benade, 1990, p. 134), is common to all instruments that “ring (and decay away) in response to an impulsive stimulus” (Benade, 1990, p. 62). All overtones are, in fact, slightly inharmonic – or almost harmonic –, because the loops of a v.m. are shorter than the mathematical subdivision of the string length for that mode, due to the node being a physical point and not a mathematical point, as Carrillo (1956, p. 105) has shown.[128] Beats may also be perceived, a phenomenon which should be due to the closeness of frequencies radiated by the body solely or of the body and the string, since the frequencies of the partials radiated only by the string are too distant apart.

The maximum overall loudness of the sounds is, like with that of the sounds of harmonics, lower than that of open-string and stopped-string sounds. These kinds of sounds consist of fewer partials, the energies of which then add to a lower loudness level. Moreover, there is energy transfer of all v.ms. to the touching surface, being this greater in multiphonics because most v.ms are touched at a loop. Our perception of the partials' relative loudness, and thus of the sounds' colour does not always correspond to their relative strengths. This is due to the frequency dependence of the ear's sensitivity to sound pressure level, and to the masking effect (Meyer, 2009, pp. 6-13). The relative loudness of the partials may then be higher or lower than their relative strength. Moreover, when partials of similar amplitude lie in the same critical band, it is not possible to form a separate loudness impression thereof (Meyer, 2009, p. 10).

2.3.3 Research question

The lack of research on the amplification of the sounds of multiphonics lead to ask whether it introduces novelty to an audience relatively to the non-amplified sounds. Otherwise the technique is not suitable for live performance on the amplified guitar. It was then necessary to investigate if amplification allows an audience to perceive main partials that otherwise are only perceivable to the player. “Small sound detail (which is usually synonymous with high frequency presence) demands close microphone proximity”, stresses Emmerson (2007, p. 127). This is because higher frequencies are more attenuated with distance, due to their preferential absorption by the air (Eargle, 2004, pp.17-18). This effect does not particularly affect the higher

[127] In this case, their frequencies are higher than integer multiples.

[128] According to Devoto (2011, p. 67), Carrillo was nominated for the Nobel prize of physics in 1950 for this finding.

main partials of the sounds of multiphonics on the wound strings of the guitar. The level of the weaker components, however, reaches the threshold of hearing at a shorter distance. Therefore the following hypothesis was formulated: *The amplification with close microphone placement of sounds of multiphonics introduces novelty to an audience, because the audience would otherwise not perceive some of the sounds' main components, regardless of room size.* Testing this positive, new colours would then be revealed to an audience. Furthermore, when left vibrating they could be enjoyed for a longer period of time. Finally, connotation with the non-amplified instrument would be avoided.

3 Methodology

> In poetry and in many other forms of creative expression investigation may take an entirely intellectual and metaphysical path, but in music, because of the very nature of the art, it must take also a *physical* path.
> Harry Partch[129]

The research hypothesis was tested in a scientific experiment involving a sample of guitarists and close microphone placement. The methodology concerning this experiment is presented in section 3.1. Some of its criteria attempt to overcome some of the gaps and problems found in literature. Artistic research was also carried out to investigate the *tremolato* as form of articulation of the string when the fundamental is to be perceived as a pedal tone. The results from the experiment and assumptions based thereon were implemented in two musical pieces. The methodology concerning the artistic research and the implementation of results is presented in section 3.2.

3.1 Scientific Research

The guitarists were recorded playing a set of takes of string 6 lightly touched at established locations and left to vibrate. The recordings were then spectrally analysed at selected time segments, and the data was treated and evaluated taking psychoacoustics into account. Apart from the determining the main partials of the sounds, their reliability, and their relative loudness at two time segment, to determine the influence of amplification on the audibility of the sounds' weaker main partials, the feasibility of the multiphonics and the reliability of the sounds were also determined, in order the know the suitability of the location in live performance. Subsections 3.1.1 to 3.1.3 discuss the criteria used to establish the conditions for the data collection, treatment and evaluation. Subsection 3.1.4 presents the method used.

3.1.1 Criteria: Data collection

Sample

A sample was used, in order to obtain results that take into account the influence of the differences in guitars and players. Two types of non-probabilty sampling were used together: purposive and convenience sampling (Saumure & Given, 2008). Purposive sampling was used because quality in the executions was desired. From the population of classical guitar players, only professional or semi-

[129] In H. Partch, *Genesis of a music*, p. xv.

professional guitarists were thereby invited. Moreover, they were told that a concert situation was desired. Convenience sampling was used, because there were only two days available to carry out the recordings at the institution hosting the sessions and travel costs could not be afforded. Therefore, the number of participants and their level of experience were subject to the availability of professional or semi-professional guitarists on those two days in the city in which the recording sessions took place.

Sound production

Touch locations

A formalised approach was used to establish locations that are easy to visually situate. The use of this kind of locations should have aided in obtaining measurements with good replicability and repeatability.[130] When not at a fret, the uncertainty in visually situating locations is greatest at locations between the last fret and the saddle. This uncertainty diminishes when the locations are situated between two consecutive frets, as it is easier to find orientation references. Therefore, the string portion between the last fret and the saddle was discarded, and the touching of the string took place at the fret and at *virtual frets* (v.fs.): locations on the portions of the string between frets (or between the nut and fret I). Thinking of a virtual fret (v.f.) as one of a group of equidistant v.fs. between consecutive frets allows for good orientation references to both frets, provided that the subdivision factor between the frets is not too high. Ideally, the same subdivision should be applied to all spaces between frets. This would aid the internalisation of the locations by the guitarist, and thus, in the long term, the integration of the technique in the guitar's idiom. However, this would either limit the number of possibilities in the larger portions of the string, in case a small subdivision were used; or would not be practical for the smaller portions, in case a larger subdivision were used. It was then decided to use different subdivision factors.

Subdivision factors of six and four were used respectively up to fret VII, and from fret VII to fret XIX, as schematised in Fig. 3.1, which also depicts the nomenclature used in testing for the identification (ID) of the v.fs. This choice of subdivision factors was due to, on the one hand, the assumption that with a factor higher than six one loses orientation; and, on the other hand, the possibility of having

[130] Giesy and Allred (1985) define replicability as "the similarity of replicate experimental units of an experimental treatment at a given point in time and space that, by definition and design, are meant identical" (p. 187); and repeatability as "the similarity of responses in systems which are observed at different locations or points in time within a given research facility" (pp. 187-188).

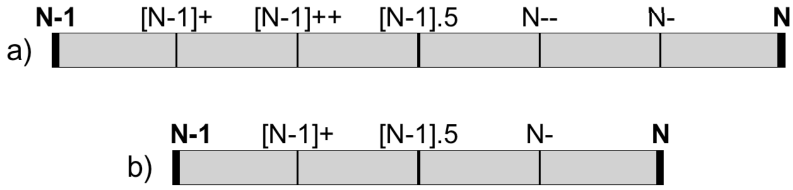


Figure 3.1. Tested virtual frets and respective nomenclature in testing
a) from the nut to fret VII; b) from fret VII to the last fret; N is the upper-fret number.

always a v.f. in the middle of the spaces, which aids in orientation. The space between frets VII and VIII was chosen for the change in the subdivision because, at this space, the subdivision in four gives rise to v.fs. which are at the same distance from each other as those between the nut and fret I of a subdivision in six. With the subdivisions used, the only v.fs. which were not tested in any of the spaces are those arising from a subdivision of the spaces in five equal parts. V.f. 0.5 (halfway between the nut and fret I) is the closest v.f. to the nut that was tested, because it is the nearest v.f. to the closest node to the nut of v.m. 39, which is the v.m. that gives rise to the highest audible partial on string 6 of the guitar of Taylor (1978, p. 32). The total of locations played amounts then to 88.

Touch pressure and duration

The touch pressure and duration were respectively lighter and shorter than in harmonics. The lighter the pressure, the smaller the surface area of the finger pad that touches the string, thus the lighter the damping, especially of the v.ms. with smaller loops. Although an extremely light pressure allows for multiphonics at all locations, it is hard to control. For which, it was decided to establish as reference pressure the lightest pressure with which harmonics are playable at the most common harmonics locations, namely at the locations giving rise to sounds, the main partial of which is partial 2, 3, 4 or 5. The lowest v.ms. need then to be damped out at these locations, otherwise the fundamental may be perceived, even if v.m. 1 is damped out, since the perception of a missing fundamental can be evoked with only two adjacent partials (Smoorenburg as cited in Schneider & Wengenroth, 2009, p. 317). The reference touch pressure was then the lightest pressure with which the fundamental is not perceived when touching at v.f. IV-(, a location from which a node of v.m. 1 is at a relative distance of 20% – this is clarified below in *Prediction …*), and was assumed to be very light. The touching took place during the excitation of the string, and was brief afterwards, in order to minimise its influence on the relative loudness results. The decay of the partials was then maximised, which is important in the case of the higher partials.

Excitation of the string

The excitation of the string took place by plucking near the bridge with nail – the narrowest of the traditional exciters (the other is the fingerpad) – to pursue the excitation as strong as possible of as many v.ms. as possible.[131] A rest stroke was used, in order to compensate for the lesser excitation of the lower v.ms. due to plucking near the bridge (thus nearer to a node than to an antinode). The stroke was played forte to aid the excitation of the v.ms. of the soundboard, especially of the higher v.ms. Being a less common articulation request, the release form of the string was left to the player. A gradual release should have taken place. The density of the nail is not controllable.

Prediction of the main partials of the sounds at each touch location

The main partials of the sounds at each touch location were predicted up to partial 39. The mathematic model suggested by Walter (2014, pp. 16-22; see section 2.1.4) was not used here, because the locations of the v.fs. correspond to fractional divisions of the string with very high denominators, and the calculations would have been cumbersome. Instead, it was calculated for each v.m. the *relative distance* (r.d.) of its nearest *main node* from the location. A main node of a v.m. is hereafter a node at which that v.m. is the lowest v.m. sharing it (a v.m. gives rise to a main partial when touched near a main node). The r.d. of a node from a touch location is its distance from the location relatively to the loop length of the lowest v.m. sharing the node.[132] This latter concept is clarified in Fig. 3.2.

The calculated relative distances (r.ds.) can be found in the table of Appendix B (the values are all below 50%, as over this value another node is closer). The locations can be grouped in three types:

A) Locations from which all nodes but one are at an r.d. of over 20%, as for example fret XII, at which there is a main node of v.m. 2 (the ID of this kind of locations has a black background in the table of Appendix B).
B) Locations from which all nodes but one are at an r.d. of 10% or over, as for example v.f. III+, at which there is a main node of v.m. 6 (the ID of this kind of locations has a dark grey background in the table of Appendix B).
C) Locations from which more than one node is at an r.d. of less than 10%, asfor example, v.f. XIV+, represented in Fig. 3.3 (in Appendix C it is possible to find figures of this kind for each string portion between frets).The nodes with an

[131] The closest nodes of v.m. 39 from the nut and the saddle are distanced therefrom ca. 1.5 cm.

[132] The r.d of a v.m.'s closest node from the location is then half of the value of the v.m.'s r.l.d. at the location.

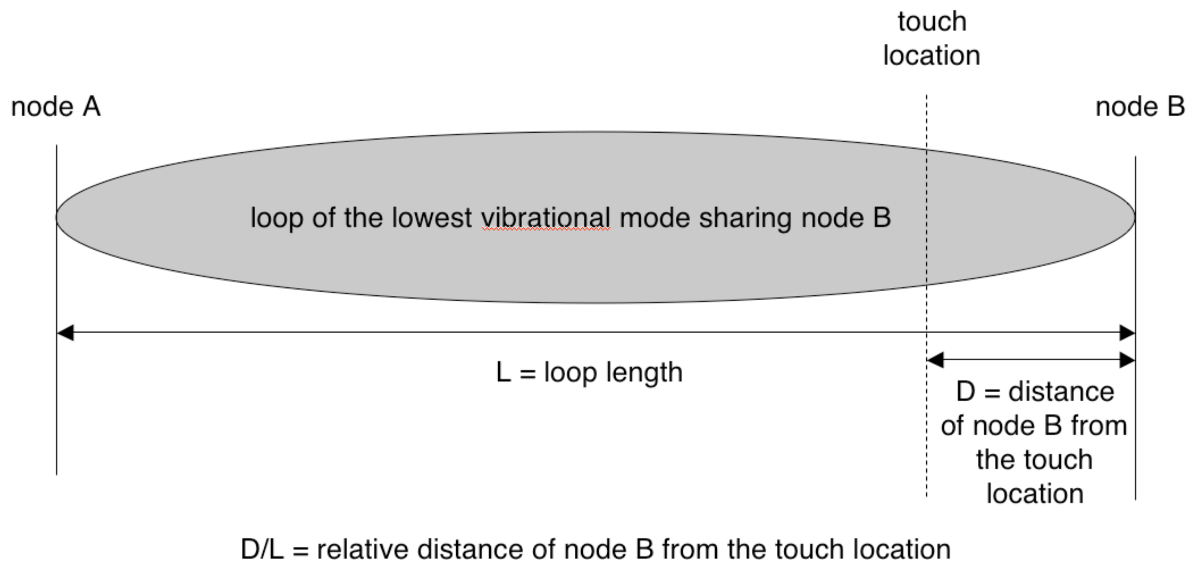


Figure 3.2. Explanation of the concept of relative distance of a node from a touch location

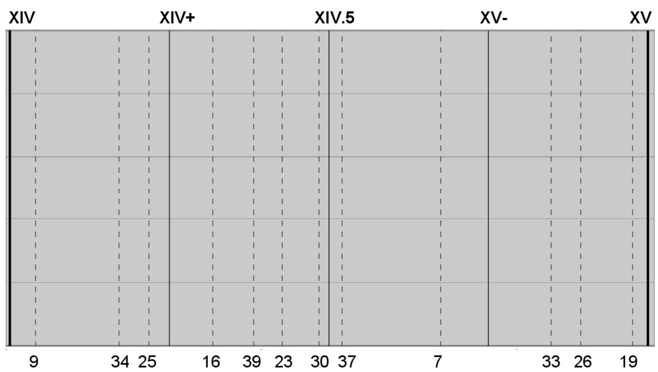


Figure 3.3. Virtual frets (solid lines) and string nodes up to those of vibrational mode 39 (dashed lines) between frets XIV and XV
Roman numerals: ID of the frets and virtual frets in testing; arabic numerals: number of the lowest vibrational mode sharing the node.

r.d. from v.f. XIV+ below 10% are, from lowest to highest r.d., main nodes of V.ms. 25, 16, 9, 34, and 7.

Type A includes frets V, VII, XII and XIX, which are usual harmonics locations. The locations at the nodes of v.m. 5 – the closest of them to the nut is between v.f. IV- and IV (it is usually played at fret IV) –, are also common harmonics locations, and all nodes are also at an r.d. of 20% or over therefrom. V.ms. with a node at an r.d. from the touch location higher than 20% (i.e., v.ms. with an r.l.d. of over 40%) should then always be damped out when using the usual harmonics touch pressure and duration. Although these were respectively lighter and shorter, the main partials of the sounds obtained at locations of types B and C were assumed to be among those given rise by the v.ms. with main nodes at an r.d. of less than 20% (with a light grey background in the table of Appendix B). At locations of type B, when the touch pressure is increased, all v.ms. but one are more easily damped out, since their nodes are at a greater r.d. from this kind of locations than from locations of type C. Types A, B, and C should then correspond respectively to kinds A, B and C described in section 2.3.2 (Sound production).

The calculated r.ds. differ slightly from the real r.ds. (except for those from the nut), because the theoretical distances of the frets from the nut were used in the calculations (in % of string length), as string compensation was ignored. String compensation accounts for the difference in the string's tension when the string is stopped, either by using a slightly longer string length (Fletcher & Rossing, 1991, p. 228), or by shifting the frets to the nut (Jahnel, 1996, p. 152).[133] The nodes betweenthe nut and a location (with negative r.ds. in the table of Appendix B) are then actually closer to the location, and those at a location, or between a location and the saddle (with positive r.ds. in the table of Appendix B) are more distant from the location. The smaller the loop of a v.m., the greater the difference between the calculated r.d. and the real r.d.

Sound recording

Space

The recordings took place in a large studio which is also used as a concert room, to obtain results as close as possible to a concert situation, and because recording low-level sounds in a (small) studio presents problems, as Morris (2002) experienced:

> As the overall volume level of the work is very low[,] ... we couldn't get much of a natural reverberation, which I did not like. We solved this problem by amplifying both the guitar and the [pitched] glasses and then recording at a lower level. ... Most recording studios are designed for dryness, which is a great problem. (p. 19)

Number of takes

As other sounds were also recorded, the number of takes had to be minimised. With three takes, if one goes wrong, there are still two takes that can be taken into account. Moreover, it allows to identify, for each location, possible trends in the executions.

[133] The string is longer 1 to 5 mm (which corresponds to ca. 1.5 to 7.7‰ of string length) on acoustic guitars, requiring more compensation bass strings than treble strings, steel strings than nylon strings, and high-action strings (larger clearance between strings and frets) than low-action strings (Fletcher & Rossing, 1991, p. 228).

Amplification

When partials are strongly damped, they may be poorly radiated in one or other zone, given that the parts of the guitar radiate preferentially in different frequency ranges. Therefore, the sounds were recorded simultaneously with microphones of the same model at different positions along the guitar, in order to identify the partials with poorer radiation, thus with lower reliability, at each location. Condenser microphones were used, due to their "extremely high quality output, and … the relative accuracy and strength of their very high frequency response" (Stark, 1996, p. 84), and also because these microphones most accurately reproduce impulsive sounds (Meinel, 1991, p. 61). Given the low level of the sounds, or of some of their components, high sensitivity microphones were used and positioned close to the guitar. Omnidirectional microphones were required, since, according to Rumsey and McCormick (2002), when acoustic labyrinths are present (the case of directional microphones) "coloration of the sound is rather more likely" (p. 66), and at short distances the proximity effect is felt (p. 59).

The parts of the guitar in front of which the microphones were positioned and at which they should aim are standard in microphone placement and close-placement procedure (Albrecht, 2010, p. 50; Bartlett, 1981, p. 729; Owsinski, 2009, p. 190). According to Bartlett (1981, pp. 730-731), when compared to a microphone at a distance of 1m, the close placement of a microphone (a) in front of the sound hole gives rise to a bass boost, due to the strong resonances of the enclosed air; (b) in front of fret XII de-emphasises the mid-bass area, because the microphone is more distant from the soundboard – the sound is characterised by a good presence and high frequencies; (c) above the neck gives rise to acoustic cancellations of various soundboard v.ms., resulting in a timbre weak in mid-range frequencies; (d) in front of the bridge gives rise to "a fairly well-balanced" timbre with, however, some mid-bass emphasis due to closeness to the soundboard. In front of fret XII there is then a better balance between lower and higher partials, for which this microphone was used to determine the relative loudness of the partials. Given that only three microphones of the same model were available, the position in front of the bridge was discarded because the excitation of the string took place near the bridge, and this shades the radiated sound around that area. The distances of the microphones from the guitar were as close as possible after ensuring that there is enough space around the guitarist so that possible bumping into the microphone is not a stress factor.

3.1.2 Criteria: Data treatment

Editing

When cutting the recording sessions files for analysis, the pre-scratch was left out of each sound. The pre-scratch is "the sound component that precedes the actual tone (...) caused by the finger rubbing along the string before it releases it" (Bader, 2005, p. 161).[134] It was left out, in order to minimise differences in the time span between the beginning of the sound file and the attack.

Spectral analysis

Each sound was subjected to a partial tracking analysis at two time segments. This was carried out with an analysis tool that allowed batch processing, given the quantity of sounds that were analysed (264 per participant and microphone [135]). The analysis took into account the same number of partials as that considered in the prediction of the main partials (i.e., 39). The first time segment (t.s. 1) was situated right after the initial transient of the sound,[136] which lasts approximately 50 ms (Bader, 2005, p. 134), in order to determine the feasibility of multiphonics, the main partials of the sounds, and the relative loudness of the main partials. This latter information is only significant when the string is rapidly repeatedly excited. If the string is left to vibrate freely, values from a later point in the sound's decay are more appropriate, because, if the spectral pitch mechanism is activated in the auditory system, it takes longer to discern the partials, especially the higher partials (Roederer, 1995, p. 150). Higher partials have however shorter decays. In fact, the spectral centroid of the soundboard, which reaches a value of 2678 Hz in the initial transient, falls to 502 Hz after 500 ms (Bader, 2005, p. 153). The second time segment (t.s. 2) started therefore at this point of the sound's decay. It should be stressed that, by this point of the sound's decay, the loudness of each partial was influenced by the touch duration. The duration of the time segments was the minimal appropriate duration, thus that of the window size, which was based on the frequency of the open string when approximately a half-tone lower. This takes into account a possible negative deviation due to a lowering in the tuning. A duration of the partials smaller than the duration of the time segments was allowed. This takes into account the possibility that their detection stops before the end of the time segment, due to a quicker damping caused by a longer touch duration; or, starts

[134] The string is in contact with the nail for ca. 100 ms (Rossing, 2010, p.17).

[135] 264 = 88 locations * 3 takes/location

[136] In the initial transient of the sound, complex interactions take place between the string and the soundboard, as the former tries to "convince" the latter "to vibrate at the string's frequency rather than its own" (Schneider, 1985, p. 26).

later, due to a longer initial transient – a characteristic of the lower partials (Meyer, 1985, p. 11). The value for the minimum duration was based on the extrapolated value (from values of Hartman [1998, p. 319]) of the tone-pitch threshold[137] of the frequency of the open string.

Sorting and statistics

The frequency and amplitude values of each predicted main partial of the sounds at each location were selected from the analysis data. Single-take detections were discarded, as they were considered not representative. The most common loudest main partial (l.m.p.) among the t.s. 2 data of all guitars was set as reference to calculate the relative amplitude levels of each of the other main partials. The l.m.p. was determined with the aid of the 40-phon equal loudness curve (the reference for low-level tones [Moore, 1989, p. 53]), despite this being for pure and isolated tones. Partials lasting shorter than a time segment were discarded if more than one take is available in which the partial lasts the whole segment, otherwise error is introduced when calculating relative amplitude mean levels (in case the l.m.p. was discarded, that time segment was discarded).

3.1.3 Criteria: Data evaluation

Perception is fundamental. Calculations, systems, theories, models and contemplation are simply irrelevant if they are not aligned with perception.
Natasha Barrett[138]

Main partials of the sounds and respective reliability

The main partials of the sounds were determined by evaluating the detection degree of the partials in t.s. 1. Their reliability was determined by evaluating their detection degree in t.s. 2. Both these degrees were categorised as high, moderate, low or very low, based on the number of guitars and microphones in the data of which the partial was detected. The main partials of the sounds were considered to be those with a high or moderate detection degree. The reliability scale follows the detection degree scale; non-detected partials in t.s. 2 were considered not reliable.

Relative loudness of each main partial

The relative loudness (r.l.) of each main partial in each time segment of each guitar and of the sample at each touch location was determined by visually evaluating the plotting of the relative amplitude mean levels (at the microphone in front of fret XII) together with 10-phon-spaced equal loudness curves normalised to

[137] The shortest duration for which a tone burst sounds mainly like a tone.

[138] In N. Barrett. Trends in electroacoustic music, p. 253.

Table 3.1. Assumptions for total masking (string 6)

Masker partial (M)	Masking up to partial		Total masking up to level difference of
	Lower partials	Higher partials	
1, 2	M -1	M+18	-25 dB
3 to 5		M+6	
6 to 39		M+4	-30 dB

the l.m.p., which was assumed to have a 40-phon loudness.[139] The r.l. of a partial depends then on the frequency of the l.m.p. For the frequency range of the investigated partials, the lower the frequency of the l.m.p., the higher the r.l of a partial. Some partials may not be perceived or be perceived softer due to, respectively, total masking or partial masking by another partial. This depends on the frequency and the sound pressure level separation of both partials (Meyer, 2009, pp. 10-13). Total masking was taken into account when evaluating the r.l. of the partials of the sample. The assumptions therefor can be found in Table 3.1. These were based on values for the masking of pure tones by pure tones (Fastl & Zwicker, 2007, pp. 68, 69[140]) together with values of the 40-phon curve, as the masker was assumed to have this loudness. The r.l. of each main partial was categorised according to the loudness zone of its r.l. in the sample. A partial was categorised loud, when this r.l. is higher than -10 phon, and moderately loud, soft, or very soft when the r.l. lies respectively between -20 and -10 phon, -30 and -20 phon, and -40 and -30 phon. Partials with an r.l. of -40 phon or less, or totally masked, were categorised as not perceivable.

The audibility of the partials in a concert room was based on values for sound attenuation with distance. For a distance of 3.8 m the attenuation of sound is -10 dB, whereas for distances of 12 m and 38 m the attenuation is -20 dB and -30 dB, respectively (Eargle, 2004, p. 18). This means that, approximately, without amplification, very soft partials are audible up to 4 m, and soft and moderately loud partials are audible up to 12 m and 38 m, respectively. Very soft partials should then only be perceived by the guitarist, and soft partials should be hard to perceive by an audience in the front rows of a room. Here, moderately loud and loud partials should be audible, but not, respectively, in the back of a medium-sized room and in a large

[139] A difference of -10 phon corresponds at 1000 Hz to -10 dB and is perceived for single tones as half as loud (Meyer, 2009, p. 10). For tones lasting less than 250 ms the perceived loudness level is is lower than expected from the corresponding sound pressure level (e.g. at 100 ms the difference is ca. 2.5 dB) (Meyer, 2009, p. 8).

[140] These values are for a masker of 1 kHz and may be predicted for other masker frequencies above 500 Hz by shifting the curves horizontally until the maximum appears at the masker frequency. They were, however, also used for masker frequencies below 500 Hz.

room.

Feasibility of multiphonics

The feasibility of multiphonics at each location was related to the number of guitarists who successfully played multiphonics right after the attack. This was assumed to have taken place when the r.l. in t.s.1 of at least one main partial (other than the l.m.p.) is higher than the highest r.l. of non-predicted main partials of the sounds at type-A locations. Since the reference touch pressure was lighter than the usual pressure in harmonics, the v.ms. with nodes at the smallest r.d. from type-A locations were not always damped out during excitation, but, instead, during the touching (which is quite short for our auditory system to single the partials out). The r.ls. of some of the main partials of the sounds at locations of type B and C should, nevertheless, be higher r.ls. than those non-predicted partials, since the nodes of their corresponding v.ms. are at smaller r.ds. from the location. The frequency and amplitude values of non-predicted main partials were then selected from the data of type-A locations, but only when they were detected in more guitars than the majority, as otherwise they were considered not representative. The feasibility of multiphonics was categorised as high, moderate, low or very low. When none of the guitarists played multiphonics successfully, the technique was categorised as not feasible.

Reliability of the sounds of multiphonics

A guitarist produced reliable sounds of multiphonics when these maintained in t.s. 2 at at least two microphones the main partials (other than the l.m.p.) which contributed to the successful playing of multiphonics right after the attack. This was because the damping out of partials with a lower r.l. should be less perceivable. The reliability of the sounds of multiphonics at each location was categorised as high, moderate, low or very low, based on the number of guitarists who produced reliable sounds. When at a location the l.m.p. is the only partial with moderate or high reliability, the sounds of multiphonics were categorised as not reliable.

3.1.4 Method

Participants and Apparatus

Guitarists and guitars

Three professional guitarists and two master-level students with experience in the professional music world (four male and one female), all right-handed, took part in the recording sessions. After they had agreed to participate they received playing instructionsper e-mail . These are reproduced in Appendix D. Each guitarist used his/her own (concert) guitar. The specifications of the guitars can be found in Table

3.2, and those of the strings in Table 3.3.

Room

The recordings took place in a large studio, which is also used as a concert room, and sits around 150 persons.[141] During the recording sessions it had, however, no chairs. The wooden walls of the half of the room to which the microphones were pointing at were covered with cloth curtains. A carpet was placed on the (wooden floor) area where the guitarists and microphones stood. The guitarists sat on a piano bench; three used a footstool and two used a leg support.

Hardware and Software

Table 3.4 summarises the recording and editing hardware and software. The three microphones used consisted of the model MKH 800 by Sennheiser. This is a small-diaphragm microphone with switchable pick-up pattern. It was used in the omnidirectional mode with the pre-attenuation, roll-off filter and treble emphasis switches off. Table 3.5 contains technical data for this model. The signals of the microphones were amplified with a Stagetec Nexus Xmic, converted and routed with a Stagetec Nexus system and recorded with a Pro Tools HD3 system. The editing of the recordings was done with a Pro Tools LE system. The application Pm2 (version 1.6.25), one of the kernels of IRCAM's Audiosculpt, was used for the analysis of the recorded data. This command-line application takes advantage of Unix shell functionality, allowing thus batch processing, for which no other option was found at the time. The analysis files were converted to text files using the droplet SDIFToText from Audiosculpt. The text data was manually copied to spreadsheets, in which conversions, statistics, and plotting were then carried out.

Procedure

Sound recording

The microphones were placed at distance of 30 cm at the following positions: in front of fret XII[142] aiming at it (M1); in front of the sound hole aiming at it (M2); and above the neck aiming at it (M3). Fig. 3.4 demonstrates this set-up. The gain of the microphones at the pre-amplifier was adjusted to have approximately the same pick-up level. Table 3.6 contains the pre-amplifier gains of each microphone. The gains differ for guitar 5, because this guitarist was recorded one day earlier than the other four guitarists, and the sound engineer decided to optimize the values in the following sessions. The sounds were recorded in separate tracks at a frequency of

[141] Goebel (2009, p. 244) gives a detailed description of the room (“large studio”). Plans and photos can be found in ZKM (n.d.).

[142] Where usually the body meets the neck.

Table 3.2. Guitar specifications (all have a string length of 65 cm)

Guitar	Constructor	No. / Year	Top	Sides & Back	Neck
1	Sérgio Abreu (Brasil)	OS-NWR /2006	Pine	Indian rosewood	Mahogany
2	Philipp Neumann (Germany)	- / 2008	Cedar	Indian rosewood	Cherry
3	José López Bellido (Spain)	1ª / 1994	Cedar	Indian rosewood	n/a
4	Daniel Chiesa (Italy)	- / 2010	Indian rosewood	Cherry	Cherry
5	Thomas Amberger (Germany)	01/11/04	Bavarian spruce	Indian rosewood	Mahogany

Table 3.3. Strings specifications and usage on the day of the recording (B: bass, T: treble)

Guitar	Manufacturer	Model	Tension	Usage
1	Augustine	T: Regals B: Blue	High	two days of moderate playing
2	T: D'Addario	J46	High	two months of moderate playing
	B: Augustine	Blue		one week of moderate playing
3	Hannabach	T: Silver	Medium	one week of intensive playing
		B: Silver 200	Med./high	
4	Hannabach	Silver 200	Med./high	three weeks of moderate playing
5	Savarez	T: Alliance B: Corum	High	None – put a few hours before session

Table 3.4. Recording and editing hardware and software

Step	Hardware/Software	Manufacturer/Developer I Model
Recording	Microphone	Sennheiser I MKH 800
	Microphone pre-amplifier	Stagetec I Nexus Xmic
	Audio format-conversion and routing system	Stagetec I Nexus
	Digital audio workstation Interface Software version	Digidesign[143] I Pro Tools HD3 Digi 192 9
Editing	Digital audio workstation Interface Software version	Digidesign I Pro Tools LE Digi 002 8.0.3

48 kHz and with a 24-bit encoding.

143 Presently *Avid.*

Sound production

The guitars were tuned to 442 Hz. The sounds at each location were played one after another in one take starting from v.f. 0.5. It was only possible to record two takes (instead of three) with guitarist 5, due to lack of time. Before playing each sound, the guitarists said the location ID and waited about half a second thereafter. When playing, they were asked to mute all other strings, pluck near the bridge with nail, forte and rest stroke, touch briefly with a pressure similar to the reference pressure and let the sound decay for about one second. After playing the sounds, they were asked to maintain the left hand near the fingerboard, take time to prepare the following location and wait about half a second before proceeding. No mention was made to the finger which should touch the string. The open strings were recorded with the same excitation conditions at the beginning of each take, in order to have an idea of the inharmonicity of the partials when sorting their data. Guitarists 3 and 4 were present at each other's session and each read the location's name out loud for the colleague, because that made it easier for them to concentrate on the location. This resulted not being a very good idea, and take 2 of guitarist 4 had to be repeated because the speaking took place very soon after the plucking (it was named T2-02). In one take, guitarist 5 forgot to play location VII+; guitarist 2 played the locations between frets VI and VII with a subdivision of four. For which, the number of elements of the sample is four, and not five, at locations VI+, VI++, VII--, VII- and VII+.

Editing

Individual sound files of no less than 600 ms were created for the sounds at each touch location. As the pre-scratch was cut, the time span that remains for sound files of the same take and different microphones is just the phase difference; for sound files of different takes, there is a time span due to differences in cutting. This is for most of those sound files no longer than 10 ms, and for very few cases 15 ms. This value was nevertheless taken into account and added to the 50 ms planned for the beginning of t.s. 1. The sound files were all heard. Those that contained execution disturbances in the first time segment or voice tone in both time segments were discarded; those with disturbances in only the second time segment or voice tone in one of the time segments were flagged. The sound files that were analysed are included in the enclosed Data-CD.

Spectral analysis

Each sound file was subjected in both time segments to a "Chord Sequence" (cs) analysis in the Inharmonic Partial Averaging mode. This calculates the average

Table 3.5. Technical data of the Sennheiser MKH 800 microphone

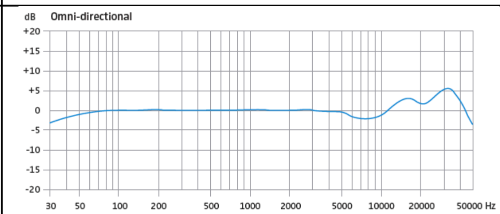
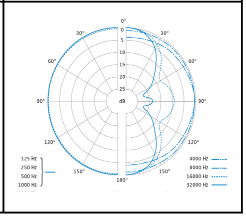
Sensitivity (mV/Pa)	Eq. noise level (dBA)	Frequency response curve	Polar diagram
40	10		

Table 3.6. Gain of the microphones at the pre-amplifier

Microphone	Position	Pre-amplifier Gain (dB)	
		Guitars 1-4	Guitar 5
M1	In front fret XII (XII)	31	28
M2	In front of sound hole (SH)	28	26
M3	Above neck (N)	37	33

Figure 3.4. Guitarists and microphone set-up

over the time segment of the values obtained with the Partial Tracking Analysis in the inharmonic mode (Lithaud, Boggaards & Roebel, 2008, chap. 21.6.3). The values used for each analysis parameter and an explanation thereof can be found in Table

3.7. The SDIF-format files in which the tool supplies the results were converted to text files, in order to obtain lists of frequency and amplitude values. Per sound file there are two analysis files, one for each time segment.

Sorting and statistics

For the data of each location and microphone the following steps were undertaken:

A. For the data of each take's time segments without execution disturbances or voice tone:

1. For an easier sorting the frequency of each detected component was converted to its factor (n) to the theoretical open-string fundamental frequency, and the linear amplitude values were converted into decibels relative to full-scale (dBFS).
2. The level values of M1 and M3 were normalised to those of M2.
3. The l.m.p. was sorted.
4. Non-predicted main partials were sorted (lower partials of the other strings were excluded – they should have been muted, but not all guitarists took this precaution).
5. The main partials were selected from the data of each time segment when they last the whole segment (except when this does not take place in the other two takes) and n does not differ from the expected value more than 0.1. If a partial is weak, the detected frequency value right after the attack might have been thatof the nearest body resonance (if the partial is too weak, the resonance value prevails). These cases were discarded if values from two other takes were available in which n lies within the premises. Due to inharmonicity (and according to the experimental values for the open string), an extra positive variation of n was taken into account. This was of 0.1 for n between 17 and 25; 0.2 for n between 26 and 30; 0.3 to 0.5 for n between 31 and 39. G4 and G5's tuning lowered during the session, for which only negative variations up to 0.5 (depending on the partial) were considered.
6. Partials in t.s.2 were discarded when n differs from the t.s.1 value more than 0.1.
7. The relative amplitude was calculated.

B. For the data of each guitarist's set of takes:

1. Partials detected in only one take were discarded.
2. The relative amplitude mean and standard deviation (s.d.) of each main partial were calculated and plotted together with equal-loudness curves extrapolated (Newton Excel Bach, 2009) from norm ISO 266:2003 values (Tackett, 2005),

Table 3.7. Spectral analysis parameters and values used (max.: maximum value possible)

Parameter		Value	Explanation
Maximum Number of Partials		39 (78 for the open string)	No. of partials to be looked for. For the open string the value was different because not all first 39 partials would be detected, since other partials are louder.
Amplitude Threshold		-120 dB [max.]	Minimum amplitude of a partial for it to be considered.
Use Markers of Type...		Hand Added: 64-128 ms; 505-569 ms	Beginning and end of the time segments, being the former the centre of the first analysis window. Both segments start at a centre of a window of an analysis starting from the beginning of the sound file, which was also carried out for possible consultation.
Relative Minimum Partial Length		51% [of t.s.(=32ms)]	Min. length for inclusion. Set to be higher than the tone-pitch threshold of the freq. of 78 Hz (28 ms).
FFT Settings	Window Size	78 Hz / 3077 samples / 64.1 ms	No. of samples in each window. The application sets it to be five times greater than that of the period of the fundamental freq. (Lithaud, Boggaards and Roebel, 2008, chap. 21.1.2).
	Window Type	Blackman [default]	Variation to be applied to the signal's strength in a window. Blackman gives usually the best results (Lithaud, Boggaards and Roebel, chap. 21.1.4).
	Window Step	Manual: 12.5% of window size [=8 ms; default]	Time gap between the beginning of two successive windows. 12.5% is better than the 25% suggested by Lithaud, Boggaards and Roebel (chap. 21.1.2).
	FFT Size	32x [max.] (131072 bins)	No. of analysis points in oversampling factor. It corresponds to a freq. resolution of 0.37 Hz.
Peak Connection [connection of peaks in successive windows]	Relative Frequency Deviation	0 cents	Allowed variance of the relative-freq. distance. The higher the freq., the greater the absolute-freq. distance to which a relative freq. distance corresponds. This might lead to the connection of peaks of different higher partials, and was thus set to zero.
	Constant Frequency Deviation	8 Hz	Allowed variance of the absolute-freq. distance. Set to be greater than 3/4 of a tone of partial 1, due to possibly still stabilising frequencies in t.s.1.
	Relative Amplitude Deviation	50% [default]	Allowed variance of the relative-amplitude distance.
	Source Partial Neighbors	1 [default]	Possible source candidate for local connection optimising.
	Target Partial Neighbors	3 [default]	Possible target candidates.
Partial Connection [connection of fragments]	Time Gap to Connect Over	0.015 s	Max. temporal distance. It was set to be smaller than twice the window step, in order to only connect adjacent fragments.
	Frequency Gap to Connect	0.0 cents	Max. relative-freq. distance. It was set to zero, since only adjacent fragments are connected and, if their peaks were not connected, the constant freq. deviation is greater than allowed.
	Minimum Partial Length	0.007 s	Min. length of a fragment for connection. It was set to value smaller than the window step, in order to not have fragments discarded.

and normalised to the l.m.p. An example can be found in Fig. 3.5.

C. For the data of each set of takes of the sample:

1. The number of guitars in the data of which a partial was detected wascounted. When in one guitar a partial was detected in t.s.2 but not in t.s.1, the guitar was accounted for if the partial was detected in one of the other two microphones (in most of these cases, the partial was detected in one take of the microphone in question).
2. The relative-amplitude mean and s.d. for each main partial was calculated and plotted together with the normalised e.l. curves, using different symbols to differentiate the number of guitars in the data of which a partial was detected, as exemplified in Fig. 3.6.

   The treated data can be found in Volume 2.

Detection degrees of each main partial

The detection degrees of each main partial were each considered to be high when the partial was detected in the data of all microphones of at least four guitars; moderate when detected in the data of two microphones of at least four guitars, or of all microphones of three guitars; very low when detected in the data of only one guitar; and low for all other cases.

Technique feasibility degrees

The (M1) results show that the r.l. in t.s.1 of all selected non-predicted main partials at type-A locations is lower than -10 phon. A guitarist was considered then to have successfully played multiphonics right after the attack when the (M1) r.l. mean of at least one partial is approximately equal or higher than -10 phon. The feasibility of the technique was considered to be high when at least four guitarists successfully played multiphonics right after the attack, and moderate, low, or very low when, respectively, three, two, or only one guitarist(s) achieved this. For the five locations for which there is data from only four guitarists the probability correspondence is: high – at least three guitars; moderate – two guitars; low – one guitar.

S*ound reliability degrees*

The reliability of the sounds was considered to be high when at least four guitarists produced reliable sounds, and moderate, low, or very low when this was the case of, respectively, three, two, and only one guitarist(s). For the five locations for which there is data from only four guitarists the probability correspondence is: high – at least three guitars; moderate – two guitars; low – one guitar.

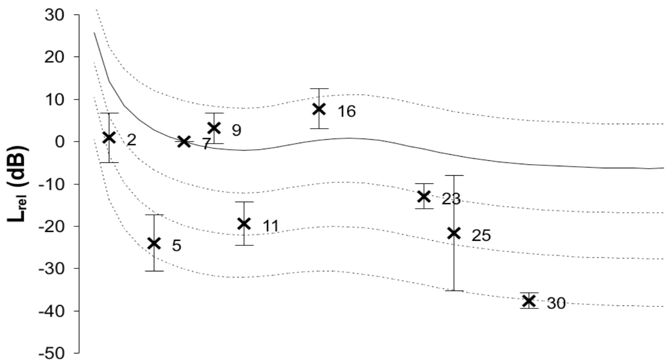


Figure 3.5. Example of the plotting of the average analysis data at t.s 2 of a set of takes at the same touch location (fret X) by the same guitarist (1) at the same microphone (M1)

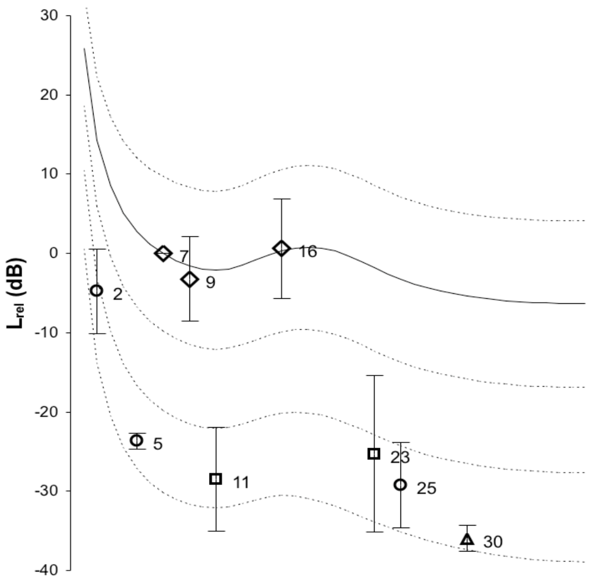


Figure 3.6. Example of the plotting of the average analysis data at t.s. 2 of a set of takes at the same touch location (fret X) by the sample at the same microphone (M1)

3.2 Artistic Research and Implementation of Results

> It will take time, the experience of ... players, and above all the challenge of electronic processing and new orchestrations, for these notions to grow into a mature technique.
> Jean-Pierre Robert [144]

The results from the scientific research and assumptions based thereon were implemented in a piece for amplified guitar and electronics, and in a guitar piece for which the articulation of the string with *tremolato* in the constant presence of the fundamental as a pedal tone was researched. Subsection 3.2.1 gives account of the methodology of this research, as well as of the ideas and compositional approach of

[144] In J.-P. Robert, *Modes of playing the double bass: A dictionary of sound*, p. 21.

both pieces. Subsection 3.2.2 discusses the criteria for the notation of touch locations and main partials.

3.2.1 Composition

> Each tool (instrument, medium, technique) is like a language, able to express some things inexpressible by others of its kind, and yet full of commonality with them. Each may severely limit the nature of one's creative output but in the cause of revealing with a clearer focus a unique delimited aesthetic domain.
>
> Laurie Spiegel[145]

***The fireflies, twinkling among leaves, make the stars wonder* for amplified guitar and live electronics**

To use the sounds of multiphonics left to ring after a single attack as a main compositional element, a background against which this take place was created, making use of flash patterns of lightning bugs, which led to the use of live electronics. This idea departed from the title of a piece for string quartet and electronics by the present piece's dedicatee, Francisco Huguet. The string quartet is entitled *Más de mil luciérnagas* (More than a thousand fireflies, 2007), and is dedicated to the victims of the El Mozote massacre, which took place in 1981 in and around the village of El Mozote in El Salvador, causing over a 1000 victims. Visiting the village after the massacre, the only living creatures that a journalist could find were fireflies, visible only during the night (Moscote, 2011) – thus Huguet's title. The very suitable and inspiring title of the present piece is an epigram by the Indian poet Rabindranath Tagore, found as epigraph to a paper (Lewis & Cratsley, 2008, p. 294).

Fireflies is the vernacular name of the insects of the *Lampyridae* family. Most of its species are bioluminescent (i.e., they chemically produce light), usually with the purpose of mating. In many species, the lantern of males is larger than that of females (Lewis & Cratsley, 2008, p. 306). Typically in yellow-green light, some species emit a steady or slowly modulated glow (Glowworms) whereas others emit flashes (Lightning bugs). In fact, some of the latter species emit in precision synchrony (Lloyd, 2004, p. 841). In glowworms, non-glowing males usually respond to the glow of flightless females (Lloyd, 2004, p. 851). In turn, in many genera of lightning bugs, males emit in patterns and females (usually at rest, regardless of their flying capability) respond at a precise time interval after a flash (Lloyd, 2004, pp. 851-852). The responses of some species are mimicked by females of many species of the genus *Photuris,* in order to eat the males of those species, therefore being called *femmes fatales* (Lewis & Cratsley, 2008 p. 311). Each species has usually an

[145] In L. Spiegel, Laurie Spiegel, p. 73.

unique pattern but more than one pattern has been found in some species (Lloyd, 2004, p. 853). A male flash consists of one or more pulses and that of females consists typically of a single pulse. The characteristics of a pattern, which change with temperature (McDermott & Buck, 1959, p. 101), are:

- the flash interval: time interval between the beginning of consecutive flashes
- the pulse duration: time interval between the beginning and the end of a pulse
- the interpulse interval: time interval between the beginning of consecutive pulses
- the character of the pulse: either steady or flickering
- the colour and brightness of the light
- the female response delay: time interval between the beginning of the last pulse of the male flash and the beginning of the female response

(Lewis & Cratsley, 2008, p. 303; McDermott & Buck, 1959, p. 94). The sounds chosen for the flashes' pulses are the highest-pitched component of the (soft) tones that result from striking a string with a plectrum (the string needs then to be muted on its nut side). The tones on this side of the string string offer the advantage of being amplified by the guitar body but the disadvantage of exciting the first air resonance, especially if struck near the bridge, for which this zone was avoided; nevertheless the soundboard should be damped. It is also convenient to play this kind of sounds with a dead stroke (i.e., the plectrum remains on the string after striking), in order to avoid noises when lifting the plectrum. As these tones are of a very short duration, only flash patterns with steady pulses lasting less than 200 ms were used. Moreover, all patterns have pulses of a fixed duration, and have a fixed flash interval, or a flash interval varying within fixed parameters. Table 3.8 contains characteristics of flash patterns under these conditions of 23 species of the genera *Photinus* and *Photuris* (two of the species have variants). The approximate musical notation of the resulting rhythms of the patterns can be found in Fig. 3.7.

Live electronics was used, in order to have a greater flexibility in the instrumental writing. For example, in combining many flash patterns, and in playing multiphonics against the complex combination. The term *live electronics* is nowadays applied to different situations. Its main paradigms are: (a) “signal processing of live instrument or voice and/or their combination with pre-recorded material (sometimes referred to as 'mixed' electronic music)”; (b) “'event processing' in so-called 'real-time' …, driving usually synthetic sounds with relatively little signal processing, any acoustic instrument becoming progressively optional”; (c) “the combination of all the previous possibilities in an open mix of event, signal and pre-recorded sound processing but usually omitting any production of acoustic sound" (Emmerson, 2007, pp. 15-16). Amplification of the instrument/voice is common when using live electronics, "to create a greater sense of ensemble between the acoustic and electroacoustic action", as it "brings the audience 'closer' to the acoustic instrument" (Barrett, 2009, 5.2 Sound and the live action). Real-time processing of the instrument is another technique used to unify both worlds, as it "captures the performed energy" (Barrett, 2009, 5.2 Sound and the live action). When pre-recorded material is used, in some compositional approaches "the instrument aspires to the acousmatic, in others the acousmatic adopts instrumental sounds and gestures, or perhaps they cohabit but remain sonically separate" (Emmerson, 2007, p. 104). Although the two kinds of sounds may aesthetically be close, "the [technical and methodological] differences between sounds molded in the studio and material transformed live during a performance are clearly audible" (Barrett, 2009, 2. Studio sound and live sound). They may, however, be used constructively to "create a continuum between a close relationship to the sound of the live instrument and a sense of otherness" (Barrett, 2009, 6. Discussion). This was not the case in this piece, as pre-recorded sound was not used, in spite of this allowing the use of the sounds (1) that arise from locations at which the technique lacks high feasibility, or (2) that lack high reliability, thus to make use of the entire multiphonics sound-palette. Event processing is the main kind of processing of the piece, and the only kinds of signal processing are the amplification of the instrument and sampling.

Live electronics allows for transformation of the acoustic sound at various levels. There are two main paradigms of the relationship of live electronics with the instrument/voice. In the first, "the machine seeks to extend the instrument out from its roots, possibly developing spatial timbral transformations and articulations but remaining rooted in its source" (Emmerson, 2009, p. 169). In the second paradigm, "the computer generates *another performer* (or more than one)", either by "displacing timbre, time, or other cues to generate a polyphony from the soloist", or by "generating an independent musical stream" (Emmerson, 2009, pp. 169-170). The motion involved in the transformation of the sound is then only of qualitative timbral change in the first paradigm, whereas in the second paradigm it is of space and/or time (Emmerson, 2009, p. 174). In fact, Barrett (2009, 5.3 Temporal issues) sees the three above-mentioned possibilities as three different time scales of displacement between acoustic and electroacoustic sound. The first paradigm corresponds to an "immediate live transformation: the performed action is immediately coupled to a live electroacoustic action. The transformation takes the live audio as its source." The two possibilities of the second paradigm correspond respectively to a "structural live transformation" and a "conceptual live transformation." In the first of these "the electroacoustic action may happen before the performed action" or thereafter, "within a time delay in which our perception finds relevance to the present." In a conceptual live transformation, "the electroacoustic material, although taken directly from the live performance at one point in time, involves a large temporal dislocation such that traces of 'real time' are remote." In this piece, the routing of the instrument's signal to the loudspeakers is the only kind of immediate live transformation. Structural and conceptual live transformations can be found extensively in the background of flash patterns.

The first flash of each male pattern is played by the guitar. The pattern is then continued by the electronics and projected in the front part of the room; when variable, the flash intervals are randomly selected by the computer. The female responses are played exclusively by the electronics and are differentiated by a slight reduction of the sound's loudness, which reflects their smaller lantern size, and by being projected in the back part of the room. Each species was made correspond to a different strike location on the string, according to genus and to the brightness of the pulses (the two species with variants need to be struck at a fret, in order to obtain the same pitch): given the aggressive behaviour of the *Photuris* females, the pitches of this genus' species were chosen to be lower than those of the *Photinus* species; among each genus, the weaker the brightness of the pulse, the higher the pitch. The sounds of the *Photinus* responses are substituted after a while by the sounds of *Photuris* species, reflecting their mimicry behaviour. In the end of the piece, the *Photinus* patterns that were mimicked stop before those of the *Photuris* species, reflecting the latter's aggressive behaviour.

The sounds of multiphonics were only introduced after all male flashes were introduced by the live instrument. This allows the guitarist to concentrate only on the playing of multiphonics, since any modification of the pattern background (namely, the introduction of responses, and the ending of patterns) is done by the electronics. The sounds were chosen for their colour. In most cases, the string is excited with moderate force and a free stroke, to obtain darker sounds and a softer excitation thud, for which the softest main partials of the results may not be audible. The technique is also used on strings 4 and 5, to produce sounds which turn into sounds of harmonics shortly after the attack. The sounds of multiphonics are projected in all loudspeakers.

There is a third kind of sounds in the piece, namely that produced by rubbing one of the three lower strings with a side of a (worn) plectrum (in order to be rugged) at an angle of ca. 45º. The main purpose of this choice was to make less evident the start of the noise of the loudspeakers, by slowly increasing their gain while a sound

Table 3.8. Characteristics of flash patterns of firefly species of the genera *Photinus* and *Photuris*

Photinus values from, or calculated from graphical representations in, Lewis & Cratsley (2008, p. 303) (*) and McDermott & Buck (1959, p. 103). *Photuris* values calculated from graphical representations in Lloyd (2004, p. 855). ** value from Bodin (2012)

Species	Flash interval (s)	No. of pulses	Pulse duration (ms)	Interpulse interval (ms)	Brightness	Female response (s)
Photuris potomaca	0.7	1	138	n/a	strong	n/a
Photinus naevus	1	1	116	n/a	strong	n/a
Photuris frontalis	1	1	138	n/a	mod. strong	n/a
Photinus ceratus (var. a)	1-1.5	2	87	145	strong	n/a
Photinus gracilobus	1-2	1	174	n/a	mod. strong	n/a
Photinus nothus	1-2	1	145	n/a	mod. strong	n/a
Photinus euphotus	1.5	1	145	n/a	strong	n/a
Photuris hebes salinus	2	1	138	n/a	weak	n/a
Photinus alticola	2	1	116	n/a	mod. strong	n/a
Photinus lobatus	2-3	1	116	n/a	mod. strong	n/a
Photinus harveyi	3	2	145	261	mod. strong	n/a
*Photinus sabulosus**	3.75	1	125	n/a	n/a	0.5
Photuris aureolucens	4	1	138	n/a	weak	n/a
Photuris cinctipennis	4	1	138	n/a	weak	n/a
Photinus amplus	4-5	2	145	232	strong	n/a
Photuris, Primitive unnamed	5	1	138	n/a	mod. strong	n/a
*Photinus greeni**	5	2	125	1333	n/a	0.75
Photuris versicolor, triple flash (Delaware)	5	3	69	100	strong	n/a
Photuris versicolor var. *quadrifulgens*	5	4	69	100	strong	n/a
Photuris versicolor	5	6	69	100	strong to mod. strong	n/a
*Photinus consanguineus**	5.25	2	166	500	n/a	1.25
Photuris fairchildi	5.6	2	138	660	mod. strong	n/a
Photinus ceratus (var. b)	5-10	3	87	145	strong	n/a
*Photinus macdermotti**	6	2	125	2000	n/a	1.25
Photuris, Tree top species	7.5	1	138	n/a	strong	n/a
*Photinus consimilis**	11**	8	80	333	n/a	6

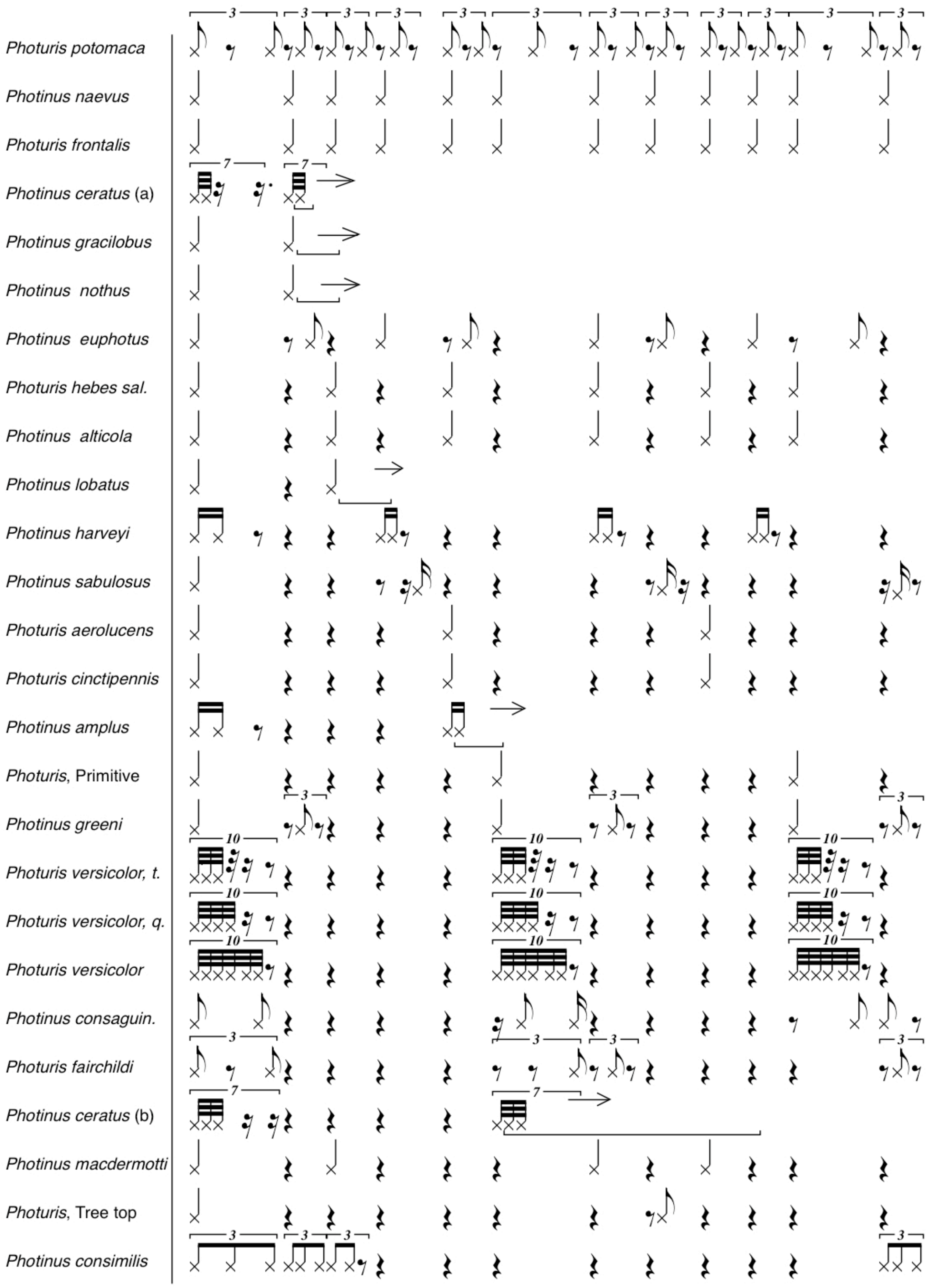


Figure 3.7. Male flash patterns of Table 3.8 in approximate musical notation

Metronome: 60 beats/minute. Pulse durations were not taken into account. Only one flash was notated for patterns with a variable flash interval, using its lowest value and showing the possible variation graphically.

of that kind is continuously played, as if opening a curtain in front of the loudspeakers, which is closed in the end in the absence of tones. Moreover, the sounds symbolise both the glows of glowworms and the flight of the lightning-bug males. These sounds are always played by the live instrument, but only at the fretboard or at the sound hole, otherwise the noise component is much louder than the tone component; and they are projected in the front part of the room.

***Si amanece, nos vamos* for guitar**

This piece was written to meet the request of guitarist Jürgen Ruck to contribute to his project *Caprichos* Goyescos. The project consists of short musical caprichos for guitar by various composers, illustrating the set of 80 prints *Los Caprichos* (1797-1798) by the Spanish painter Francisco Goya. The chosen *Capricho* was number 71, *Si amanece, nos Vamos* (If day breaks, we will be off).[146] This print depicts a group of five witches under a starry sky; behind them is the black silhouette of a figure with wings. Four witches are sitting on the ground and one is sitting on what Tal (2006) has called “an excrescence in a shape of a disembodied anus, a signifier of the inverted nature of witchcraft” (p. 158). This witch is pointing to the sky and has strapped to her back (at least) two small children. Witches were thought to consume the flesh of babies at Sabbats (Dore, 2008, p. 13). This meal is one of the events of the standard set that supposedly occurred during a Sabbat:

> The Sabbat was located in a churchyard, the foot of the gallows or at the summit of a mountain at night, usually at midnight or at the latest by dawn. Flying on a broomstick or an animal was the means of travel to the night-time meeting where the Devil would also appear often in the form of an animal. The witches glorified the Devil, kneeling down to him, kissing on his left foot or anus. Witches would confess their sins and were punished for not performing enough *maleficia*. There was a service, a parody of the divine service, and then a meal followed by 'an orgiastic dance to the sound of trumpets, fifes and drums'. ... The Devil would have sexual relations with the participants, and he would then dismiss the group. (Dore, 2008, p. 13)

The scene takes then place before the meal of a Sabbat. Interpreting the silhouette as a symbol of the devil that is yet to arrive, the witches have just settled down and are getting ready for their ritual. In fact, contrary to other witchcraft prints of the *Caprichos*, this print suggests quietness and not movement, which is emphasised by the starry night scenery. The black silhouette creates, however, an atmosphere of

[146] Museo Nacional del Prado (2015) provides a reproduction of the print (Estampas, Caprichos, 8) and preparatory drawing (Dibujos, Preparatorio series de grabados, Caprichos, 6)

suspense.

When the composition of the piece started it was already known that its premiere would take place in a church. Notwithstanding, the piece was written having in mind a small or medium-sized concert room, appropriate for a guitar recital, and where most certainly other performances are to take place. Some sounds and gestures were inspired on the above-described imagery. Noises resulting from the rubbing of the strings were inspired on the noise of a broomstick sweeping the ground, and on the wind noise in a(n imaginary) broomstick flight. The underlying suspense created by the silhouette inspired a pedal tone (i.e., a continuously sustained note) on the lowest pitch of the guitar (the open string 6), based on which the most piece was composed. This was also a form of overcoming the lack of sustain of the guitar. The only forms of playing a continuous (or almost continuous) tone is by rapidly repeatedly exciting the string, either with the *tremolo* (i.e., alternating the fingers p, a, m and i) or the *tremolato* (i.e., plucking downwards and upwards with a single exciter),[147] or by exciting the string with a bow. The element of suspense is, however, greater with the *tremolo* or the *tremolato*. Given that with the *tremolo* the excitation location differs with each finger, the *tremolato* was used, in order to avoid differences in each sound. Since this kind if articulation limits the possibilities of excitation of the other strings, and the string on which the technique of multiphonics was tested was to be used by the pedal tone, it was decided to explore the articulation of multiphonics with the *tremolato* while maintaining the presence of the pedal tone in the sounds. For which the usual harmonics locations were also included. The other determinate locations of the piece are exclusively the tested locations, and they were chosen for the sounds' colour. The (almost) continuous sound of the *tremolato*, being the result of the repetition of the attack of a singly plucked sound, allows to obtain sounds in which the partials that decay rapidly are more audible, thus to obtain tone colours that are often not perceivable when the sounds are left to ring (it also eliminates sound reliability problems). The r.l. of the partials in distant field was assumed to be that of the (near field) scientific results of the first time segment, but only the loud partials were taken into account, since the other partials are not expected to be perceived by a whole audience.

[147] The terms *tremolo* or *tremolato* is in general the rapid repetition of one ore more notes. On the guitar, however, the term *tremolo* is strongly associated with the *pami* technique, thus the use of *tremolato* for the other form of excitation (see Rebizzi and Tajè [1987]).

3.2.2 Notation of multiphonics

> A major problem in the compositional use of these new sound resources has been to develop a notation which is both sufficiently detailed (requiring lots of information about timbre and about modes of production, normally taken for granted in a conventional notation) and yet sufficiently clear to be read in performance (requiring as little information as possible!).
> Trevor Wishart[148]

Like with harmonics, it is possible to notate the action and/or the result in multiphonics. When the fundamental of a sound of harmonics is low pitched, often only the result is provided, as the guitarist knows where to play the sound. This might not be true when the fundamental is higher pitched, and it is most certainly not true for sounds of multiphonics. It is then essential to indicate the touch location, by notating which string and fretboard location are played. When the result is not provided at locations at which it is possible to play both harmonics and multiphonics, it is necessary to make the technique explicit. This is also necessary at all kind of locations when only one (or two) pitch(es) is notated, and this pitch should be emphasised, which should be explained. Specifying the relative loudness of the pitches determines to some extent other timbral characteristics of the sound (e.g., brightness). In case these are to be more detailed, other descriptors are needed, which should nevertheless be used, because not all players (a) might be able to perceive multiple pitches; (b) might be well acquainted with sound production in multiphonics; (c) pay attention to the result, preferring to concentrate on sound production descriptors. Therefore, including descriptors such as the touch pressure and duration, kind of stroke, and exciter assures that the result approximates what the composer intends. For this purpose, the sound's colour (e.g., dark, balanced) and/or connotation (e.g., bell-like) may also be useful. To avoid excess of information, only non-conventional playing conditions should be characterised and notated (e.g., excitation with finger flesh). Given that the technique is not common to the vocabulary of the guitar, an explanation thereof and of its notation should always be included in the score.

Touch locations

The touch locations may be notated in various ways. The choice of a specific notation should depend, for example, on the compositional approach or the extent of the use of different sounds of multiphonics. It could be argued that the use of different notations may not help the assimilation of multiphonics into the vocabulary of the guitar. This was, however, not the case with harmonics for which “notations which lie far behind a desired normalisation” have been used along the guitar's

[148] In T. Wishart, Extended vocal technique, p. 314.

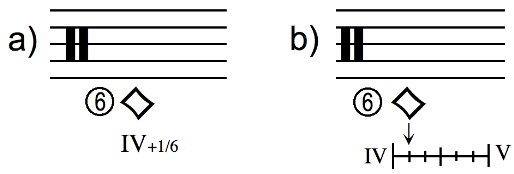


Figure 3.8. Examples for the same touch location of two forms of notating the lightly touching of an open string at a virtual fret without using pitch notation for the latter
Both notations presuppose an explanation in the performance instructions.

history (Gimeno, 2011, p. A58).[149] Nevertheless, it is necessary to have notations that unequivocally identify the v.fs. that result from the different subdivisions of a space between two consecutive frets, which was not the case of the nomenclature used in testing (see Fig. 3.1). Fig. 3.8 presents two forms of notation of a v.f. that do no make use of pitch notation. In the kind of notation of Fig. 3.8a, a positive or negative fraction, depending on which side of the fret is the location, after the fret number allows each v.f. to have its own ID, and is more simple than using decimal numbers (it is noted that, although two of the v.fs. arising from a subdivision of a portion of the string in six are the same as those arising from a subdivision in three, using the notation of $N+\frac{2}{6}$ and $N-\frac{2}{6}$ instead of that of respectively $N+\frac{1}{3}$ and $N-\frac{1}{3}$ might be useful when the touching previously took place at $N+\frac{1}{6}$ or $N-\frac{1}{6}$). The graphical representation of Fig. 3.8b is more straightforward, but requires more space, which makes it less practical to continuously notate multiphonics.

There are guitarists who prefer, however, symbolic pitch notation. Different microtonal accidentals for each v.f. between two consecutive frets are then required. As Fig. 3.9 shows, the location of the v.fs. does not differ much from the theoretical locations where the string would be stopped if the same subdivision would be applied to the halftone (e.g., a subdivision of the halftone in six equal parts would mean stopping twelfth-tones). Therefore, accidentals from the *Extended Helmholtz-Ellis Just Intonation Pitch Notation* system (Sabat & Von Schweinitz, 2004) were chosen which alter the pitch of the nearest fret by amounts similar to those which would result from stopping the string at the v.fs. These accidentals are depicted in Fig. 3.10. In Figs. 3.11a-d it is possible to find the location of Fig. 3.8 notated with one of the accidentals.[150] If, on the one hand, the double notation of the v.f. in Figs. 3.11c and 3.11d is redundant, on the other hand, it suits all tastes.

[149] Original version: notaciones que están muy lejos de una deseable normalización.

[150] Fifteen members an audience of 31 guitarists preferred notation b of Fig. 3.8 when presented to that figure and to Fig. 3.11a-d. The notation of Fig. 3.11a was the choice of one audience member, and that of Fig. 3.11b was the choice of another. The rest of the audience did not reply.

Other notation systems such as Ben Johnston's *Extended Just Intonation* (Fonville, 1991) and Secor and Keenan's (2004) *Saggital* notation would serve the same purpose as that of Sabat and Sabat (2004). Their symbols are, however, less straightforward. In turn, the symbols suggested by Criton and Delume (2009, n. pag.) specifically for twelfth-tones on the guitar are more straightforward than those of Sabat and Sabat, as only numbers and conventional accidentals are used. The symbols consist of natural and sharp accidentals with a subscript containing a number between one and five, which are used respectively for the pitches nearest and furthest to the pitch notated with the conventional accidental. To unequivocally identify with this kind of notation the v.fs. that result from the different subdivisions of a space between two consecutive frets, it is necessary to use fractions in the subscript. Using negative fractions to notate the locations nearest to the upper fret, as in Figs. 3.11e-f, is more straightforward than using large positive fractions, and using arrows instead of plus and minus signs, as in Figs. 3.11g-h, is even more straightforward. The use of a double notation when using accidentals with subscripts would be too redundant, as the subscripts already show the subdivision. Therefore the fret corresponding to the accidental without arrow is notated near the accidental.

The notations in Figs. 3.11b, 3.11d, 3.11f, and 3.11h are suitable for artificial harmonics/multiphonics, because the string is notated symbolically. In this case, to make the intention clear, the string number should also be notated when the stopped-pitch is that of open strings 4 or 5, otherwise it could also be played as natural multiphonics. The notation of Fig. 3.8a was that used in the piece for amplified guitar and electronics, in order to be coherent with the notation of the locations at which the other kinds of sounds are played, which does not use pitch symbols, because some locations are situated between the last fret and the saddle. A one-lined staff was then used as main staff, given the absence of pitch notation for the touch and strike/rub locations. The notation chosen for the piece for guitar was that of Fig. 3.11h, because it was thought to be the most appropriate due to the continuous *tremolato* on the string.

Main partials

The main partials of the sound may be notated with pitches, with partial numbers or with both. Players are, however, not used to thinking in partial numbers, and these, contrary to pitches, do not imply other partials that may also be present in the sound. Pitches are then preferable but using both suits, again, all tastes. They can be notated in parentheses (using the guitar transposition for the pitches), in a second staff (using untransposed pitches), or be supplied in the performance notes. The pitches and partial numbers were notated in parentheses in both pieces, since

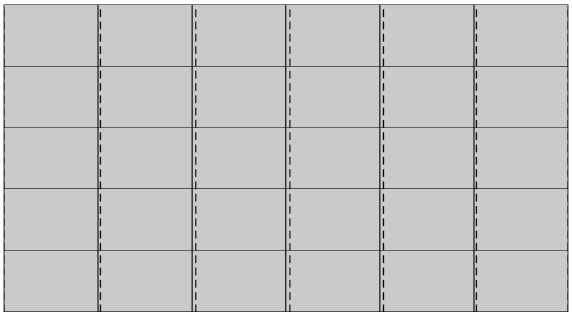


Figure 3.9. Virtual frets (solid lines) and theoretical locations of twelfth-tones (dashed lines) between consecutive frets

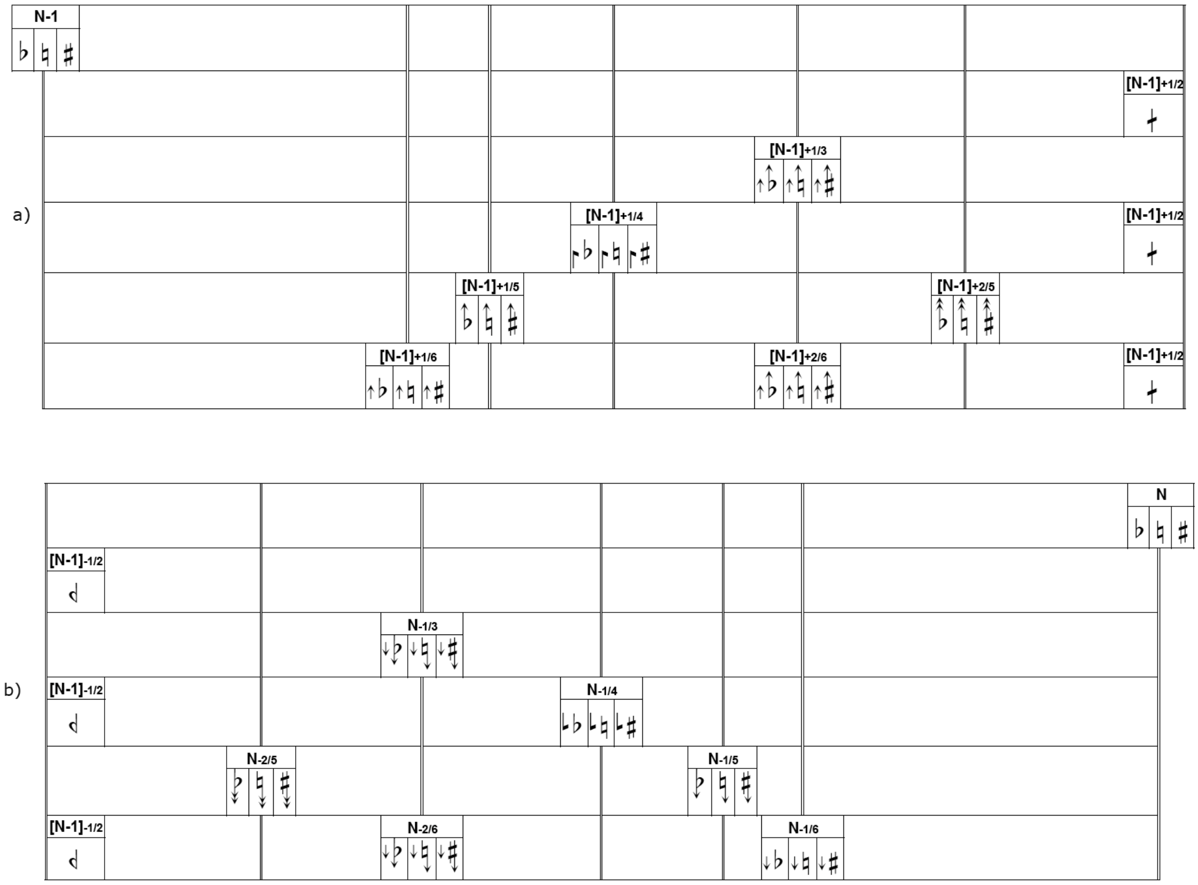


Figure 3.10. Microtonal accidentals for the symbolic pitch notation of virtual frets
The accidentals were taken from the *Extended Helmholtz-Ellis Just Intonation Pitch Notation* system (Sabat & Von Schweinitz, 2004). The figure represents to the scale the virtual frets (v.fs.) between consecutive frets which arise from the subdivision of the string portion up to six equal parts. In the nomenclature of the v.fs. N is the upper-fret number. a) from the lower fret to the middle v.f., accidentals apply to the pitch at the lower fret; b) from the middle v.f. to the upper fret, accidentals apply to the pitch at the upper fret.

the density of multiphonics was low. In regard to pitch accuracy, given the inharmonicity of the higher partials, it does not make sense to use a just intonation

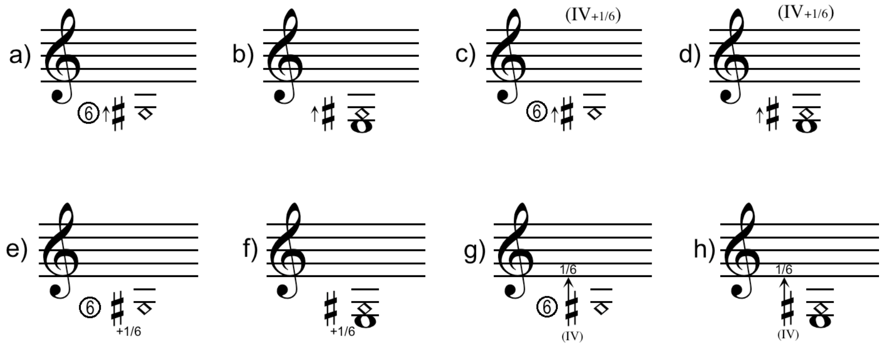


Figure 3.11. Examples for the same touch location (that of Fig. 3.8) of possible forms of notation of the lightly touching of an open string at virtual frets using symbolic pitch notation for the latter

All notations presuppose an explanation in the performance instructions.

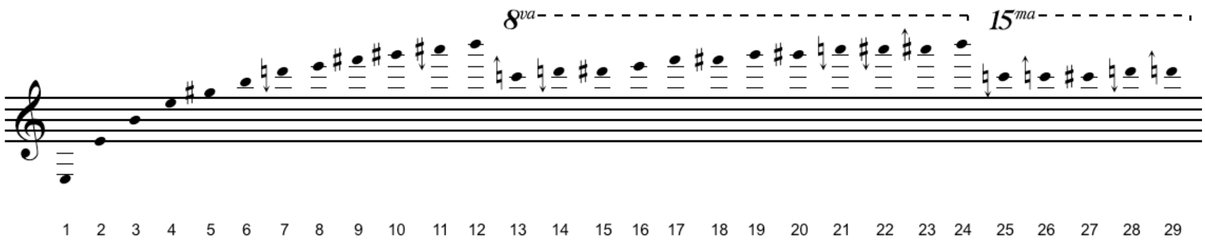


Figure 3.12. Notation (in guitar transposition) used for the pitches of the first 29 partials of the sound of the open string 6

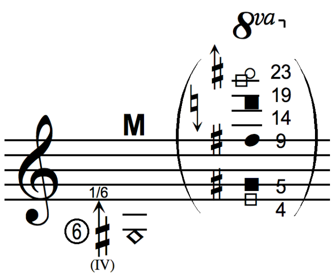


Figure 3.13. Example of the notation used for the main partials of the sounds of guitar multiphonics (same touch location as in Fig. 3.8)

The partials' relative loudness category correspondence with the note-head format is: black square – loud, black circle – moderately loud, white square – soft, white circle – very soft.

system. For which, it was decided to only notate with accidentals with an arrow the deviations from the equal temperament of more than an eighth-tone, since they are more perceivable. Fig. 3.12 depicts the notation of the pitches of the first 29 partials of the sound of the open string 6. The r.l. of the partials with moderate or high reliability was differentiated by using different colours and shapes for the note heads, as in Fig. 3.13 (only loud partials were notated in the piece for guitar).

4 Results

4.1 Scientific Research

The results for each location can be found in Appendices E through I. Appendix E presents the feasibility of multiphonics and the reliability of the sounds. Appendices F and G present the detection degree of each main partial respectively in t.s. 1 and in t.s. 2. Appendices H and I present the relative loudness category of each main partial respectively in t.s. 1 and in t.s. 2.

4.1.1 Main partials of the sounds and respective reliability

Table 4.1 presents the distribution per degree of the partials' detection in t.s. 1 among the locations at which they were predicted. Table 4.2 presents the average of this distribution for groups of partials. As these tables show, the detection degree of partials 2 to 29 was high at the majority of the locations, whereas that of partial 1 and of partials above partial 29 was mostly low or very low. The main partials of the sounds are then partials with number between 2 and 29. The poor detection of partial 1 at most locations is possibly related with the greater susceptibility to damping of v.m. 1. Its excitation strength (four times higher than all other v.ms.) is then approximated at a lower r.d. by the amount of damping it suffers. This could also explain the low detection of v.ms. higher than v.m. 29, given their low excitation strength. Some of the latter v.ms. may have been damped out also due to a deviation in the touching and/or excitation locations, or because a great part of their loop length may have been covered by the touching surface, due to a stronger touch pressure. This would also have particularly increased the damping of v.m.1.

Table 4.3 presents the distribution per degree of the partials' detection in t.s. 2 among the locations at which they were predicted. Table 4.4 presents the average of this distribution for groups of partials. As these tables show, partials 2 to 18 are highly reliable at the majority of the locations, partials 19 to 25 are, in average, highly or moderately reliable in equal proportions, and partials 26 to 29 have always low or lower reliability. The latter partials are at all reliable due to the same two guitarists (G1 and G2), which suggests that the other guitarists used a longer touch duration. The tables in Appendices F and G show that the detection degree of partial 1 in t.s. 2 follows its detection degree in t.s. 1 up to an r.d. value of ca. 10%, a value from which the partial is mostly not reliable. This suggests that its poor detection degree in t.s. 1 was, up to an r.d. of 10%, due to a stronger touch pressure on the part of some guitarists, and that for higher r.d. values the amount of damping it suffers approximates its excitation strength.

Table 4.1. Distribution (%) per degree of the partials' detection in t.s. 1 among the locations at which they were predicted

Detection	Partial number (a shading flags a majority)																			
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
High	11	71	90	92	94	100	97	100	100	100	97	100	94	100	100	100	100	100	97	94
Moderate	16	25	7	8	6	0	0	0	0	0	3	0	6	0	0	0	0	0	3	6
Low	21	4	3	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Very low	53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Not detect.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Detection	**Partial number** (a shading flags a majority)																			
	21	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	
High	95	80	81	75	79	82	78	66	66	17	5	11	5	0	0	0	3	0	0	
Moderate	3	21	19	25	18	12	13	32	32	42	32	39	10	6	13	0	9	0	0	
Low	0	0	0	0	4	6	9	3	3	42	50	50	85	88	83	64	66	25	14	
Very low	0	0	0	0	0	0	0	0	0	0	13	0	0	6	4	36	19	31	41	
Not detect.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	44	45	

Table 4.2. Average distribution (%) per degree of the detection of groups of partials in t.s. 1 among the locations at which the partials were predicted

Detection	Partial number (a shading flags a majority)				
	1	**2-21**	**22-29**	**30-37**	**38, 39**
High	11	96	75	5	0
Moderate	16	3	22	19	0
Low	21	1	3	66	19
Very low	53	0	0	10	36
Not detect.	0	0	0	0	45

4.1.2 Feasibility of multiphonics

The technique of multiphonics is feasible at all locations at which it was predicted as such. Moreover, it is feasible at v.f. XII-, at which it had been predicted as not feasible. Table 4.5 presents the locations at which the technique has moderate or lower feasibility. Except for v.f. II- and fret III, the locations are either at the main node of v.m. 6 or very near main nodes of v.m. 2, 3, 4 or 5, locations from which the main nodes of the v.ms. higher than the l.m.p. and up to v.m. 18 are at an r.d. of over 10%, and the main nodes of the v.ms. lower than the l.m.p are at an r.d. of over 16%. At such r.ds., those v.ms. are more prone to damping with an increase of the touch pressure or with a slight deviation in the touch location, and to not have

Table 4.3. Distribution (%) per degree of the partials' detection in t.s. 2 among the locations at which they were predicted

Detection	**Partial number** (a shadings flags a majority)																			
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
High	21	57	83	77	78	100	74	95	87	64	67	83	76	80	56	94	66	69	52	44
Moderate	0	11	3	15	19	0	10	5	9	36	19	8	18	13	39	6	23	15	24	25
Low	21	18	10	8	3	0	13	0	4	0	14	8	6	7	6	0	11	15	24	25
Very low	21	14	3	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	6
Not detect.	37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Detection	**Partial number** (a shading flags a majority)																			
	21	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	
High	37	33	31	8	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Moderate	21	27	42	25	46	0	9	0	0	8	0	0	0	0	0	0	0	0	0	
Low	42	40	25	50	39	71	70	73	68	50	18	50	5	0	4	0	19	0	0	
Very low	0	6	3	17	7	29	4	27	21	25	47	28	65	29	35	9	34	0	5	
Not detect.	0	0	0	0	0	0	17	0	11	17	34	22	30	71	61	91	47	100	95	

Table 4.4. Average distribution (%) per degree of the partials' detection in t.s. 2 of groups of partials among the locations at which they were predicted

Detection	**Partial number** (a shading flags a majority)					
	1	**2-19**	**19-25**	**26-29**	**30-37**	**38, 39**
High	21	77	30	0	0	0
Moderate	0	15	30	2	0	0
Low	21	7	35	70	18	0
Very low	21	1	5	20	34	2
Not detect.	37	0	0	7	47	98

enough strength to give rise to loud partials. The higher v.ms. are also more prone to damping, due to their smaller loops. The lower feasibility at v.f. II-, may be due to the linearity of loudness sensation in the frequency zone of partials 9, 10 and 11, together with the value of the r.d. from the location of the nodes of v.ms. 9 and 10. In regard to fret III, the results may have been due to a larger deviation from the touch location (towards v.f. III+), given that v.m. 13 is at an r.d. of 7% from fret III, and therefore feasibility problems should not exist. As the table in Appendix E shows, guitarists 1 to 5 played multiphonics successfully right after the attack at respectively 100, 65, 80, 81 and 90% of the locations at which the technique is feasible. The better results of guitarists 1 and 5 could be explained by the lesser usage of their strings, since the higher modes are more excitable in this situation.

Table 4.5. Locations (Loc.) with moderate or lower feasibility (Feasib.)			
Loc.	**Type**	**Feasib.**	**Main partials with moderate or high detection in t.s. 1** (relative distance [%] of the v.m.'s closest main node to the location) * l.m.p.; bold typed: r.d. < 10%
II-	C	low	9 (10) **10* (0)** 11 (10) **19 (9)** 21 (11) 28 (19) **29 (9)**
III	C	moderate	**6* (5)** 7 (11) **13 (7) 19 (2)** 20 (-18) **25 (2) 31 (7) 32 (9)**
III+	B	moderate	5 (17) **6* (0)** 7 (17) 11 (16) 13 (17) 17 (16) 19 (17) 23 (16) 25 (17) 29 (16)
IV-	B	very low	**5* (1)** 6 (19) 11 (18) 16 (17) 21 (17) 26 (16)
IV	C	moderate	4 (17) **5* (3)** 9 (14) 14 (11) **19 (8) 24 (5) 29 (2) 34 (1)**
V-	C	low	**4* (3)** 9 (19) 13 (16) 17 (14) 21 (11) **25 (9) 29 (6)**
VII-	C	low	**3* (2)** 19 (19) 22 (17) 25 (15) 28 (13)
VII+	C	low	**3* (3)** 17 (19) 23 (14) 26 (11) **29 (8) 32 (6)**
IX-	C	low	3 (19) **5* (2)** 8 (17) 13 (16) 18 (14) 23 (12) 28 (10)
IX	C	moderate	2 (19) **5* (3)** 7 (16) 12 (14) 17 (11) **22 (8) 27 (5) 32 (3)**
XII-	A	low	**2* (1)** 15 (39) 17 (37) 21 (34) 23 (33)
XII.5	C	moderate	**2* (3)** 23 (18) **29 (9) 31 (7) 33 (4)**
XIII-	C	moderate	**2* (4)** 15 (18) 17 (14) 19 (10) **21 (6) 23 (2) 25 (3) 27 (7)** 29 (11)
XVI-	B	very low	**5* (1)** 7 (18) 12 (17) 17 (15) 22 (14) 27 (13) 32 (11)
XVI	C	low	3 (19) **5* (2)** 8 (17) 13 (16) 18 (14) 23 (13) 28 (11)
XVIII.5	C	moderate	**3* (3)** 14 (19) 17 (16) 20 (13) 23 (10) **26 (7) 29 (3) 32 (0)**
XIX-	B	very low	**3* (2)** 26 (19) 29 (18)

4.1.3 Relative loudness category of each main partial

Tables 4.6 and 4.7 present an overview of the number of main partials in each r.l. category, respectively in t.s. 1 and t.s. 2. As these tables show, the sounds contain moderately loud, soft or very soft partials in t.s. 1 at 98% of the locations at which the technique of multiphonics is feasible, and in t.s. 2 at 91% of that kind of locations. When the sounds contain in t.s. 1 loud partials other than the l.m.p. and/or moderately loud partials, these partials should be difficult to damp out right after the attack. Five of the locations that give rise to these sounds are of type B, that is, they were predicted as locations at which it should be possible to also play harmonics, which should then not be true. The five locations at which the sounds contain in t.s. 1 only soft or softer main partials apart from the l.m.p. are v.fs. IV-, VII+, IX-, XVI- and XIX- (see the table of Appendix H); these are all locations very near nodes of v.ms. 3 or 5.

Table 4.8 presents the l.m.p. at each location, as well as the v.ms. with main nodes at an r.d. from the location smaller than that of the main node of the v.m. that

Table 4.6. Number of main partials (up to partial 29) in each relative loudness (r.l.) category in t.s. 1 at the locations at which the technique of multiphonics is feasible

r.l. category	**Location distribution** (number of locations)				
	40% (33)	**2%** (2)	**36%** (30)	**16%** (13)	**6%** (5)
Loud	2-7	2/9	2-6	1	1
Moderately loud	1-5	0	1-5	1-7	0
Soft	0	0	1-4	0*-6	2/4-6
Very soft	0	0	0/1	0/1#	0
Not perceivable	0	0	0	0/1	0/1

*2 locations, #1 location

Table 4.7. Number of main partials (up to partial 29) in each relative loudness (r.l.) category in t.s. 2 at the locations at which the technique of multiphonics is feasible

r.l. category	**Location distribution** (number of locations)				
	58% (48)	**2%** (2)	**10%** (8)	**22%** (18)	**8%** (7)
Loud	1-3, 4+	2/6	2/3	1	1
Moderately loud	1-5	0/4	0	0	0
Soft	0*-4	0	2-6	0-4	0
Very soft	0#-4	0	0-2	1-6	0
Not perceivable	0-4	0	0	0-4	1-5/9

+1 location,*3/#11 locations but always one of the two categories

gives rise to the l.m.p. This v.m. is for most locations the v.m. with a number between 1 and 11 which has a main node at the smallest r.d. from the location. There are only a few exceptions:

- At locations I-, I, I+, I++, I.5, IV.5, VI++, XI- and XIII.5 a v.m. higher than v.m. 11 with a main node at a smaller r.d. from the location has a degree of excitation strong enough to compete with that of the v.ms. up to v.m. 11.
- At locations III.5, VIII- and X a v.m. at a higher r.d. from the location than a v.m. up to v.m. 11 has a strong enough degree of excitation to compete therewith.
- At v.f. II+ a main node of v.m. 8 is, on the opposite side of the location, at the same distance therefrom than a main node of v.m. 9, but partial 9 is louder. This may be explained by compensation, that is, the node of v.m. 9 is, in fact, at a smaller r.d. from the location (see section 3.1.1, Sound production).

Other situations of a partial being softer than another when it should theoretically be louder may also be explained by compensation, or they may be explained by the closeness of this partial's frequency to a resonance of the guitar.

Tables 4.9 and 4.11 present the distribution per category of the partial's r.l. among the locations at which they were investigated, respectively at t.s. 1 and t.s. 2. Tables 4.10 and 4.12 present the average of this distributions for groups of partials. Partial 1 is mostly soft or softer, which may again be explained by v.m. 1 being more prone to damping. At the majority of the locations, partials 2 to 16 are loud in t.s. 1 and loud or moderately loud in t.s. 2, partials 17 to 39 are moderately loud in t.s. 1, and partials higher than partial 19 are soft or very soft in t.s. 2. There is an abrupt decrease of the percentage of locations at which partials higher than partial 16 are loud. This could be explained by the fact that above 1500 Hz (the frequency of partial 17 is 1407 Hz), the influence of the string-vibration component perpendicular to the soundboard loses significance in the direct driving thereof (Taylor, 1978, pp. 40-41 – see footnote 125). This component is enhanced by a rest stroke, which was the kind of stroke used when producing the sounds. Therefore, when the l.m.p. is lower than partial 17, the r.l. of partials higher than this partial is moderately loud or softer, even if the touching takes place very near a node of the v.m. Care should then be taken when extrapolating the results to the other wounded strings. Frequency values should be used instead of partial numbers. For example, with a rest stroke only partials up to partial 12 on string 5, and partial 9 on string 4 should be loud.

4.1.4 Reliability of the sounds of multiphonics

The sounds of multiphonics are reliable at 93% of the locations at which the technique of multiphonics is feasible. At 67% the technique feasibility and sound reliability are high. The sounds are not reliable at v.fs. 0.5, VII-, VII+, XII-, XII.5, and XIX-. Table 4.13 presents the locations at which the sounds have moderate or lower reliability, and the partials that were damped out. Except for v.fs. I-- and I-, those are locations at or very near main nodes of v.ms. 7 to 9, from which the main nodes of v.ms. 2 to 5 are at an r.d. between 10 and 15% – at these r.ds. those lower v.ms. may still be loud in t.s. 1 but are more prone to damping by a slightly longer touch duration. The lower or null sound reliability at v.fs. 0.5, I-- and I- is due the fact that, at these locations, the r.d. of main nodes of the v.ms. up to v.m. 18 is very high – all partials are more easily damped out. The fact that this situation does not lead to a lower feasibility of multiphonics at these locations has to do with the l.m.p. being partial 1 at v.fs. 0.5 and I-- and partial 21 at v.f. I-, because, in the former case, for a same relative amplitude, a partial has the greatest r.l. when the l.m.p is partial 1 ; and in the latter case, the partials have all amplitudes similar to the l.m.p.

Table 4.8. Loudest main partial (l.m.p.) at each location
In parentheses: partial(s) with which the l.m.p. competes as loudest.

Loc.	l.m.p.	v.ms. with nodes at a samller or equal r.d.		Loc.	l.m.p.	v.ms. with nodes at a samller or equal r.d.		Loc.	l.m.p.	v.ms. with nodes at a samller or equal r.d.
0.5	1	-		**V.5**	11	-		**XII+**	2	-
I--	1	26, 27		**VI--**	7	18, 25		**XII.5**	2	-
I-	21	-		**VI-**	7	-		**XIII-**	2	23, 25
I	18	-		**VI**	7	17, 24		**XIII**	2	17, 19
I+	16	15, 31		**VI+**	10	-		**XIII+**	2 (15)	13, 15, 25
I++	14 (13)	27		**VI++**	13	-		**XIII.5**	13	24, 37
I.5	12	-		**VI.5**	3	16, 19, 35		**XIV-**	11	-
II--	11	-		**VII--**	3	22, 25		**XIV**	9	-
II-	10	-		**VII-**	3	-		**XIV+**	9	16, 25
II	9	-		**VII**	3	-		**XIV.5**	7	30, 37
II+	9 (8)	8, 17, 26		**VII+**	3	-		**XV-**	7	-
II++	8	-		**VII.5**	3	17, 20, 37		**XV**	7	12, 19
II.5	7	15, 22		**VIII-**	3 (11, 14)	11, 14, 25		**XV+**	5	12, 17, 29
III--	7	-		**VIII**	8	19, 27		**XV.5**	5	22
III-	7	13, 20, 33		**VIII+**	8	29, 37		**XVI-**	5	-
III	6	19, 25		**VIII.5**	5	13, 18, 31		**XVI**	5	-
III+	6	-		**IX-**	5	-		**XVI+**	5	18, 23
III++	6	17, 23		**IX**	5	-		**XVI.5**	5	13, 18
III.5	5 (11)	11, 16, 27		**IX+**	5	12, 17		**XVII-**	8 (5, 13)	21, 29
IV--	5	16, 21, 26		**IX.5**	7	19, 26		**XVII**	8	-
IV-	5	-		**X-**	7	-		**XVII+**	8	19, 27
IV	5	-		**X**	7 (9, 16)	9, 16 25		**XVII.5**	11	-
IV+	5 (14)	14, 19, 33		**X+**	9	-		**XVIII-**	11	14, 25
IV++	9	-		**X.5**	11	-		**XVIII**	3 (14)	14, 17
IV.5	13 (4)	22, 35		**XI-**	13	-		**XVIII+**	3	20, 23
V--	4	17, 21		**XI**	2	15, 17		**XVIII.5**	3	29
V-	4	33, 37		**XI+**	2	21, 23		**XIX-**	3	-
V	4	-		**XI.5**	2	-		**XIX**	3	-
V+	4	31		**XII-**	2	-				
V++	4	15, 19, 34		**XII**	2	-				

Table 4.9. Distribution (%) per category of the partials' relative loudness (r.l.) in t.s. 1 among the locations at which they were predicted

r.l. category	**Partial number** (a shading flags a majority)																			
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Loud	11	36	83	69	84	63	61	65	48	82	64	42	62	80	67	81	51	31	27	50
Moderately loud	11	39	13	31	16	25	32	25	48	18	33	42	32	20	33	13	43	46	52	38
Soft	32	21	3	0	0	13	6	10	4	0	3	17	6	0	0	6	6	27	21	13
Very soft	47	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Not perceivable	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
r.l. category	**Partial number** (a shading flags a majority)																			
	21	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	
Loud	21	13	19	25	4	6	4	27	8	17	9	17	16	12	5	22	18	20	9	
Moderately loud	63	47	61	67	64	35	52	27	45	67	46	44	58	47	67	44	54	60	64	
Soft	16	40	19	8	32	59	43	47	47	17	40	39	21	24	29	33	29	20	9	
Very soft	0	0	0	0	0	0	0	0	0	0	3	0	0	18	0	0	0	0	18	
Not perceivable	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	

Table 4.10. Average distribution (%) per category of the relative loudness (r.l.) in t.s. 1 of groups of partials among the locations at which the partials were predicted

r.l. category	**Partial number** (a shading flags a majority)		
	1	**2-16**	**17-39**
Loud	11	66	19
Moderately loud	11	28	52
Soft	32	6	28
Very soft	47	0	2
Not perceivable	0	0	0

As the table in Appendix E shows, guitarists 1 to 5 produced reliable sounds at respectively 93, 87, 86, 84 and 53% of them. The results of guitarist 5 point to the use of a longer touch duration.

4.1.5 Summary and conclusions

The sound production conditions varied slightly, due to the degree of freedom that their description involved. It can be assumed that the touch pressure was very light to light, and that the excitation took place (with nail and a rest stroke) near or very near the bridge. With these conditions, the sounds at most investigated locations at which the technique is feasible contain moderately loud, soft or very soft main partials. The hypothesis proves then to be true: the amplification with close

Table 4.11. Distribution (%) per category of the partials' relative loudness (r.l.) in t.s. 2 among the locations at which they were predicted

r.l. category	**Partial number** (a shading flags a majority)																			
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Loud	17	37	47	54	53	50	45	45	30	36	28	25	29	40	28	31	6	8	3	6
Moderately loud	17	19	27	15	16	13	10	5	22	18	28	25	24	13	11	25	34	8	21	13
Soft	17	22	17	23	22	13	26	20	22	36	17	17	18	27	28	25	9	31	27	31
Very soft	42	19	3	0	3	0	3	0	0	9	6	17	12	13	11	6	26	23	24	44
Not perceivable	8	4	7	8	6	25	16	30	26	0	22	17	18	7	22	13	26	31	24	6
r.l. category	**Partial number** (a shading flags a majority)																			
	21	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	
Loud	5	0	3	9	4	7	5	0	3	11	7	11	0	0	0	-	0	-	-	
Moderately loud	11	13	3	0	0	0	0	9	3	11	0	0	9	25	0	-	0	-	-	
Soft	42	13	29	27	32	13	32	27	16	67	13	22	18	25	20	-	13	-	-	
Very soft	37	40	54	64	54	53	42	27	55	11	53	44	64	25	60	-	56	-	-	
Not perceivable	5	33	11	0	11	27	21	36	23	0	27	22	9	25	20	-	31	-	-	

Table 4.12. Average distribution (%) per category of the relative loudness (r.l.) in t.s. 2 of groups of partials among the locations at which the partials were predicted

r.l. category	**Partial number**			
	1	**2-16**	**17-19**	**20-36, 37**
Loud	17	39	5	4
Moderately loud	17	18	21	6
Soft	17	22	22	26
Very soft	42	7	24	46
Not perceivable	8	15	27	18

microphone placement of the sounds of multiphonics introduces novelty to an audience, regardless of room size. With amplification, it should only be also possible to play harmonics right after the attack at locations very near nodes of v.ms. 3 or 5.

At most locations at which the technique is feasible:

- the main components of the sounds are partials given rise by v.ms. with number between 2 and 29 that have a main node at an r.d. from the location up to at least 19%;
- the l.m.p. is a partial with number between 2 and 11;
- the partials up to partial 25 are the only to have have moderate or high reliability; their reliability is nevertheless low at one third of the locations;

- partials higher than partial 16 are hardly loud at any moment of the decay, and those higher than partial 19 are mostly soft or softer in t.s. 2;
- the feasibility of the technique and the reliability of the sounds at a location – thus the suitability of the location for live performance under the playing conditions of the experiment – depends on the degree of excitation of the v.ms. up to v.m. 18.

Vfs. 0.5, I--, and I- present particular cases because the main partials of the sounds are partial 1 and partials above partial 17.

Tables 4.14 and 4.15 present the number and r.l. category of the main partials with moderate or high reliability of the sounds of multiphonics at the investigated locations, respectively at t.s. 1 and t.s. 2. Table 4.16 presents the locations suggested in the scientific literature, which are the same as those of the experiment, thus for which it is possible to compare to a certain extent the main partials of each author's results. This was carried with the results of t.s. 2, since the main partials of Schneider (1985, p. 137) and Vishnick (2014, pp. 221-225) appear to be the result of auditive analyses, and those of Josel and Tsao (2014, p. 119) are the partials that last at least one second. Given that the latter authors' results stem from spectral analyses, they agree, as expected, with this experiment's results: all loud and moderately loud partials are part of Josel and Tsao's results. Moreover, soft partials are also part of some of their results, and are flagged as softer partials. This is the case of, for example, partial 17 at locations IV.5, XI- and XV+, which may be due to this partial being a strong resonance of the guitars used by those authors. The lack of loudness differentiation between the loud and moderately loud partials may be due to, on the one hand, Josel and Tsao's evaluation criteria, and on the other hand, due to the use of only player and two guitars. The results of Schneider and of Vishnick are, in turn, less coherent, since some do not include the loud and/or moderately loud partials from the results, but include soft partials.

The approach undertaken in the data evaluation allows for criteria for the categorisation of the sounds such as a same number of loud partials, l.m.p. or lowest main partial, which may be useful in selecting sounds. These categorisations can be found in Tables 4.17 to 4.21. As tables 4.17, and 4.18 show, whereas in t.s. 1 it is possible to play sounds with up to nine loud moderately or highly reliable main partials, in t.s. 2 the maximum number of loud main partials with moderate or high reliability is four, being this possible at only one location. Like Table 4.8, Table 4.19 shows that the l.m.p. is at most locations a partial between partial 2 and partial 11. According to Tables 4.20 and 4.21, the lowest main partial at the majority of the locations is partial 2, 3 or 5. It differs between t.s. 1 and t.s. 2 essentially at locations

Table 4.13. Locations (Loc.) at which the reliability of the sounds is moderate or lower

Loc.	Type	Reliability	**Main partials with moderate or high reliability** (relative distance [%] of the v.m.'s closest main node to the location) bold typed: damped out partials; * l.m.p
I--	C	moderate	1* (4) **23 (14) 25 (6)**
I-	C	moderate	1*(5) 17 (20) 18 (16) 19 (11) 20 (6) 21* (2) 22 (-3) **23 (8)**
IV++	C	moderate	**4 (12)** 5 (11) 9* (1) 13 (13) 14 (10) 22 (13) **23 (9)**
X+	C	moderate	**2 (11) 7 (13)** 9* (2) 11 (9) 13 (19) 16 (15) 20 (7)
XIV+	C	low	**2 (12)** 7 (7) 9* (5) 11 (17) 16 (3) **25 (2)**
XV-	C	moderate	**5 (13)** 7* (1) 9 (16) 12 (12) 16 (17) 19 (11)
XVII	B	moderate	3 (12) **5 (13)** 8* (0) **11 (12)** 13 (13) 19 (12) 21 (13)
XVII+	C	moderate	**3 (11) 5 (15)** 8* (5) 11 (6) 14 (17) 19 (2)

from which main nodes of v.ms. 2 and 3 are at greater r.ds. – although these suffer a strong amount of damping, this is not sufficient to damp them out or leave them unperceived right after the attack.

4.2 Artistic Research and Implementation of Results

4.2.1 *The fireflies, twinkling among leaves, make the stars wonder* for amplified guitar and live electronics

The score of the piece can be found in Volume 2 in a draft version. The piece starts with string 3 being rubbed with the plectrum while the gain of the loudspeakers is increased. It follows a short phrase with the same kind of sounds, and thereafter (on rehearsal number I), a kind of transitional cadence with sounds resulting from the striking of the strings, with which the patterns background starts. For a greater flexibility, it is the guitarist who triggers the sampling of the sounds; the letters attributed to the sounds correspond to the order of the flash patterns in Table 3.8. In the section that follows there is some degree of improvisation, as the player is free to choose when to play each sound and rhythmic cell, as well as when to play therebetween short sounds resulting from the rubbing of the string. The following section starts (on rehearsal number II) with the introduction of the five *Photinus* female responses. It follows an electronics solo, to firmly establish the patterns background. The last section (starting on rehearsal number III) is centred on multiphonics. In the first part, five different sounds are alternated in a slow tempo. In the second part, the *Photinus* female responses are replaced by those of the *Photuris* species, which is flagged by the introduction of a new sound of

(continues on p. 122)

Table 4.14. Number and relative loudness category at t.s. 1 of the main partials with moderate or high detection of the sounds of multiphonics at the investigated locations

Relative loudness category correspondence with number formatting: bold underlined: loudest main partial; bold – loud; normal – moderately loud; italic – soft; grey – very soft; parentheses – not perceivable. * moderate or lower technique feasibility

Loc.	Main partials	Loc.	Main partials	Loc.	Main partials
0.5	**1**	V.5	**4**, **7**, **11**, 15,18, *19,* 26, 29	XII+	technique not feasible
I--	**1**, **22-29**	VI--	**3**, **4**, **7**, **11**, 15, **18**, 25, 29	XII.5*	**2,** 23, 29
I-	1, **18-20, 21, 22-24**, 25	VI-	**3**, 4, **7**, **10**, 11, 17, 18, 24,*25*	XIII-*	**2**,15,**17**,19,**21**,**23**,*25*,27,29
I	1, **15-17, 18, 19, 20**, 21	VI	**3**, 4, **7**, **10**, 13, **17**, 24, 27	XIII	**2**,**11**,**13, 15, 17, 19, 21**, 23
I+	13, **14, 15, 16, 17**, 18, 29	VI+	**3**, **7**, **10**, **13**, **17**, 23, *24,* 27	XIII+	**2**,9,**11**,**13**,**15**,**17**,19, **24, 28**
I++	11,12,**13**,**14**,15,16,*25*,27+	VI++	**3**, 7, **10**, **13**, **16**, *19*, 23, 29	XIII.5	2, 9, **11**, **13**, **15**, 20, 24, 28
I.5	**10, 11, 12, 13, 14**, **23**, 25	VI.5	**3**,7,10,**13**,**16**,19,22,*23,25,29*	XIV-	2, 7, **9, 11, 13, 20,** 24, **29**
II--	9, **10, 11, 12**, 13, 21, **23**	VII--	**3**, 10, 13, **16**, 19, 22, 25, *28*	XIV	2, **7**, **9**, **11, 16, 20,** 25, 29
II-*	9, **10**, 11, 19, 21, *28*, *29*	VII-*	**3**, *19, 22, 25,* 28	XIV+	2, **7**, **9**, 11, **16**, 23, 25
II	**8, 9**, **10**, 17, **19**, *26*, **28**, 29	VII	technique not feasible	XIV.5	2, **5**, **7**, 9, **16**, 23, 25
II+	**8**, **9**, **10**, **17**, 25, 26	VII+*	**3**, *17, 20, 23, 26, 29*	XV-	*2*, **5**, **7**, 9 12, 16, *19,23,26*
II++	**7**, **8**, 9, **15**, 17, 23, *25*	VII.5	**3**, 8, 11, **14**, **17**, 20,23,*26,29*	XV	2, **5**, **7**, **12**, 17, **19**, 26
II.5	**7**, **8**, **15**, 22, 23, 29	VIII-	**3**, **8**, **11**, **14**, 17, 19, 25	XV+	*2*, **5**, 7, **12**, 17, 19, *22*, *29*
III--	6, **7** ,8, 13, 15,20,22,*27*,29	VIII	**3**, **5**, **8**, **11**, 13, 14, **19**, 27	XV.5	*2*, **5**, 7, 12, 17, *22, 27, 29*
III-	**6**, **7**, **13**, 19, **20**, 27	VIII+	**3**, **5**, **8**, 11, **13**, 18, *21*, 29	XVI-*	2, **5**, (*7*)*, 12, 17, 22, 27*
III*	**6**, 7, **13**, 19, *20*, 25	VIII.5	*3*, **5**, 8, **13**,18, *21*, 23, 28	XVI *	3, **5**, *8*, 13, *18, 23, 28*
III+*	5, **6**,*7*, 11,*13*, 17,*19, 23,25*	IX-*	*3,* **5**, *8, 13, 18, 23, 28*	XVI+	3, **5**, 8, 13, 18, 23, *28*
III++	**5**, **6**, **11**, **17**, 23, 28, *29*	IX*	*2,* **5**, **7**, *12,* 17, *22, 27*	XVI.5	3, **5**, **8**, **13**, 18, *21, 23, 29*
III.5	**5**, **6**, **11**, **16**, 17, 21, 27,*28*	IX+	*2,* **5**, 7, 12, **17**,*19*, 22, *27, 29*	XVII-	**3**, **5**, **8**, 11, **13**, 18, 21, 29
IV--	**5**, 6, 11, **16**, 21, *26*, *27*	IX.5	2, **5**, **7**, **12**, 17, **19**, 26	XVII	**3, 5, 8, 11**, 13,19,21,*27*,29
IV-*	**5**, *6*, (*11*), *16, 21, 26*	X-	*2,* 5, **7**, 9, 12, **16**, *19*, 23, *26*	XVII+	**3, 5, 8, 11**, 14, 19, 27
IV*	4, **5**, 9, **14**, 19, 24, *29*	X	*2*, **5**, **7**, **9**, 11, **16**, 23, 25	XVII.5	**3**, 5, **8**, **11**, **14**,17,**19**,*25*,27
IV+	4, **5**, **9**, **14**, 19, 23, 24	X+	2, **7**, **9**, **11**, 13, **16**, **20,** 25,29	XVIII-	**3**, **8**, **11**, **14**, **17**, 19, 20, 25
IV++	**4, 5, 9, 13, 14**, 22, 23	X.5	2, 7, **9**, **11**, **13**, 15, **20**, 24,29	XVIII	**3**, 8,**11**,**14**,**17**,20,23,*25,26*
IV.5	**4**, 5, **9**, **13**, **17**, 22	XI-	2, 9, **11**, **13**, **15,** 17, 24, 28	XVIII+	**3**, 11, **14, 17, 20,** 23,*26,29*
V--	**4**, 5, 9, **13**,**17**,21,22,25,*29*	XI	**2**, **11, 13, 15,17,19**,21,23,**28**	XVIII.5*	**3**, 14, 17, 20, 23, 26, 29
V-*	**4**, (*9*), *13,* 17, 21, 25, *29*	XI+	**2, 15, 17, 19,21,23**,25,27,29	XIX-*	**3**, *26, 29*
V	technique not feasible	XI.5	**2**, 21, **23**, 25, 27, 29	XIX	technique not feasible
V+	**4**, 11, 15, 19, 23, 27	XII-*	**2, (**15, 17), 21 ,23		
V++	**4**, **7**, **11**, **15**, 19, 23, 26,*27*	XII	technique not feasible	+	**I++** *29*

Table 4.15. Number and relative loudness category at t.s. 2, of the main partials with moderate or high reliability of the sounds of multiphonics at the investigated locations

Relative loudness category correspondence with number formatting: bold underlined: loudest main partial; bold – loud; normal – moderately loud; italic – soft; grey – very soft; parentheses – not perceivable. * moderate or lower technique feasibility; ** moderate or lower sound reliability

Loc.	Main partials	Loc.	Main partials	Loc.	Main partials
0.5	sounds not reliable	V.5	**4**, **7**, **11**, *15*, *18*	XII+	technique not feasible
I--**	**1**, **23**, **25**	VI--	3, 4, **7**, 11, 15, 18, 25	XII.5*	sounds not reliable
I-**	1, (18, 19), **20**, **21**, 22, 23	VI-	*3*, *4*, **7**, *10*, (11), 18	XIII-*	**2**, (19), 23
I	1, (15), **16**, **17**, **18**, **19**, 20	VI	3, **7**, **10**, 17, *24*	XIII	**2**, (*13*), 15, 17,(*19*),21
I+	(*13*), 14, **15**, **16**, (17, 18)	VI+	3, *7*, **10**, *13*, 17, 23	XIII+	**2**, 11, **13**, **15**, 17, (*19*)
I++	(*11*),*12*,**13**,**14**,*15*,(*16*),*25*,*27*	VI++	**3**, *7*, 10, **13**, *16*, *23*	XIII.5	2, (*9*), 11, **13**, 15, 24
I.5	*10*, 11, **12**, 13, 25	VI.5	**3**, *10*, 13, **16**, 19, 22	XIV-	2, (*7*), 9, **11**, *13*, *20*
II--	*9*, 10, **11**, 12, (13), *21*, 23	VII--	**3**, 10, *16*, 19, 22, 25	XIV	2, 7, **9**, 11, 16, 20
II-*	*9*, **10**, *11*, *19*, *21*	VII-*	sounds not reliable	XIV+**	*2*, **7**, **9**, *11*, **16**, *25*
II	*8*, **9**, **10**, 17, 19	VII	technique not feasible	XIV.5	*2*, *5*, **7**, 9, 16, *23*
II+	**8**, **9**, *10*, **17**, *25*	VII+*	sounds not reliable	XV-**	*5*, **7**, (9), 12, 16, 19
II++	*7*, **8**, *9*, *15*, 17, *23*	VII.5	**3**, (8), 11, **14**, 17,*20*,23	XV	**5**, **7**, 12, 17, 19, *26*
II.5	**7**, **8**, **15**, *22*, *23*	VIII-	**3**, 8, **11**, **14**, (*17*), *25*	XV+	**5**, 7, **12**, *17*, *19*
III--	6, **7**, (8), 13, 15	VIII	3, *5*, **8**, **11**, *13*, *14*, 19	XV.5	**5**, (7), *12*, 17, 22
III-	**6**, **7**, **13**, *19*, 20	VIII+	3, 5, **8**, 11, 13, 21	XVI-*	**5**, (12, 17)
III*	**6**, (7), 13, *19*, 25	VIII.5	*3*, **5**, *8*, **13**,*18*, 21, 23	XVI *	**5**, (8, 13, 23)
III+*	(5), **6**, (13, 17)	IX-*	(3), **5**, (8), 13, (18, 23)	XVI+	**5**, (8),*13*, 18, 23
III++	5, **6**, 11, 17, *23*	IX*	**5**, (12), 17, (22)	XVI.5	**5**, *8*, **13**, *18*, 23
III.5	**5**, 6, **11**, 16, 17, 21, *27*	IX+	**5**, *7*, 12, 17, 22	XVII-	3, **5**, **8**, **13**, *18*, 21
IV--	**5**, (6), *11*, 16, *21*	IX.5	5, **7**, **12**, 17, 19	XVII**	*3*, 5, **8**, 11, *13*, 19, *21*
IV-*	**5**, (6, 11, 16)	X-	*5*, **7**, *9*, *16*, 23	XVII+**	3, *5*, **8**, 11, 14, *19*
IV*	(4), **5**, (9), 14, 19, 24	X	*2*, **7**, **9**, *11*, **16**, *23*, *25*	XVII.5	3, *5*, **8**, **11**, *14*, 17,*19*
IV+	*4*, **5**, 9, **14**, *19*, 23	X+**	*2*, 7, **9**, *11*, (13),*16*, 20	XVIII-	**3**, *8*, **11**, **14**, *17*, *25*
IV++**	4, 5, **9**, 13, 14, 22, 23	X.5	2,*7*, 9,**11**,13,(15),20,24	XVIII	**3**, (8),11,**14**,17, *20*,*25*
IV.5	**4**, *5*, 9, **13**, *17*, *22*	XI-	2, *9*, 11, **13**, *15*, (17)	XVIII+	**3**, (*11*), 14, 17, *20*, 23
V--	**4**, (5, 9), 13, 17, *21*, 25	XI	**2**, (*11*), **13**, **15**, 17,(*19*)	XVIII.5*	**3**, 14, 17, 20, 23
V-*	**4**, (9, 13)	XI+	**2**, (*15*), 17, 19, 21, *23*	XIX-*	sounds not reliable
V	technique not feasible	XI.5	**2**, 23, 25	XIX	technique not feasible
V+	**4**, *15*, 19, 23	XII-*	sounds not reliable		
V++	**4**, *7*, **11**, **15**, *19*, 23, 26	XII	technique not feasible		

Table 4.16. Locations suggested in the scientific literature (as numbered in Table 2.1) which are the same as those of the experiment (Experim.)

Experim.	Literature	Experim.	Literature	Experim.	Literature	Experim.	Literature
I.5	1	VI	11	XI-	22	XV.5	30
III++	5a	VIII	14	XI	23	XVI.5	31
III.5	5b, 5c	IX+	17a	XIV-	25	XVII.5	33
IV.5	8a, 8b	IX.5	18	XIV+	27		
V.5	9	X	20	XV+	29		

Table 4.17. Categorisation of the sounds at t.s. 1 according to the number of loud main partials (up to partial 29) with moderate or high detection

Number of loud main partials	**Locations** (loud main partials) * moderate or lower technique feasibility
1	**0.5** (1), **II-*** (10), **III--** (7), **III+*** (6), **IV-*** (5), **V-*** (4), **V+** (4), **VII-*** (3), **VII+*** (3), **IX-*** (5), **XII-*** (2), **XII.5*** (2), **XV.5** (5), **XVI-*** (5), **XVI*** (5), **XVI+** (5), **XVIII.5*** (3), **XIX-*** (3)
2	**I++** (13 14), **III*** (6 13), **IV--** (5 16), **IV*** (5 14), **VII--** (3 16), **VII.5** (3 14 17), **VIII.5** (5 13), **XV+** (5 12), **IX** (5 7), **IX+** (5 17), **X-** (7 16), **XI.5** (2 23), **XV-** (5 7),
3	**II++** (7 8 15), **II.5** (7 8 15), **IV+** (5 9 14), **V--** (4 13 17), **V.5** (4 7 11), **VI-** (3 7 10), **XIV+** (7 9 16), **XIV.5** (5 7 16), **VI.5** (3 13 16), **XI-** (11 13 15), **XIII.5** (11 13 15), **XVI.5** (5 8 13)
4	**I+** (14-17), **II--** (10-12 23), **II+** (8-10 17), **III-** (6 7 13 20), **III++** (5 6 11 17), **III.5** (5 6 11 16), **IV.5** (4 9 13 17), **V++** (4 7 11 15), **VI** (3 7 10 17), **VI++** (3 10 13 16), **VIII-** (3 8 11 14), **VIII** (3 5 8 11 19), **VIII+** (3 5 8 13), **IX.5** (5 7 12 19), **X** (5 7 9 16), **X.5** (9 11 13 20), **XIII-*** (2 17 21 23), **XV** (5 7 12 19), **XVII-** (3 5 8 13), **XVII** (3 5 8 11), **XVII+** (3 5 8 11), **XVIII** (3 11 14 17), **XVIII+** (3 14 17 20)
5	**I.5** (10-14 23), **II** (8-10 19 28), **IV++** (4 5 9 13 14), **VI--** (3 4 7 11 18), **VI+** (3 7 10 13 17), **X+** (7 9 11 16 20), **XIV-** (9 11 13 20 29), **XIV** (7 9 11 16 20), **XVII.5** (3 8 11 14 19), **XVIII-** (3 8 11 14 17),
6	**I** (15-20), **XI+** (2 15 17 19 21 23),
7	**I-** (18-24), **XI** (2 11 13 15 17 19 28), **XIII** (2 11 13 15 17 19 21), **XIII+** (2 11 13 15 17 24 28)
9	**I--** (1 22-29)

Table 4.18. Categorisation of the sounds at t.s. 2 according to the number of loud main partials with moderate or high reliability

Number of loud main partials	**Locations** (loud main partials) * moderate or lower technique feasibility; ** moderate or lower sound reliability
1	**I.5** (12), **II--** (11), **II-*** (10), **II++** (8), **III--** (7), **III*** (6), **III+*** (6), **III++** (6), **IV--** (5), **IV-*** (5), **IV*** (5), **IV++**** (9), **V--** (4), **V-*** (4), **V+** (4), **VI--** (4), **VI-** (7), **VI+** (10), **VII--** (3), **VIII+** (8), **IX-*** (5), **IX** (5), **IX+** (5), **X-** (7), **X+**** (9), **X.5** (11), **XI-** (13), **XI+** (2), **XI.5** (2), **XIII-*** (2), **XIII** (2), **XIII.5** (13), **XIV-** (11), **XIV** (9), **XIV.5** (7), **XV-**** (7), **XV.5** (5), **XVI-*** (5), **XVI*** (5), **XVI+** (5), **XVII**** (8), **XVII+**** (8), **XVIII+** (3), **XVIII.5*** (3)
2	**I-**** (20 21), **I+** (15 16), **I++** (13 14), **II** (9 10), **III.5** (5 11), **IV+** (5 14), **IV.5** (4 13), **VI** (7 10), **VI++** (3 13), **VI.5** (3 16), **VII.5** (3 14), **VIII** (8 11), **VIII.5** (5 13), **IX.5** (7 12), **XV** (5 7), **XV+** (5 12), **XVI.5** (5 13), **XVII.5** (8 11), **XVIII** (3 14)
3	**I--**** (1 23 25), **II+** (8 9 17), **II.5** (7 8 15), **III-** (6 7 13), **V++** (4 11 15), **V.5** (4 7 11), **VIII-** (3 11 14), **X** (7 9 16), **XI** (2 13 15), **XIII+** (2 13 15), **XIV+**** (7 9 16), **XVII-** (5 8 13), **XVIII-** (3 11 14)
4	**I** (16-19)

Table 4.19. Categorisation of the sounds according to the loudest main partial (l.m.p.)
[nr] sounds not reliable; * moderate or lower technique feasibility; ** moderate or lower sound reliability

l.m.p.	Locations	l.m.p.	Locations
1	0.5[nr], I--**	**10**	II-*, VI+
2	XI, XI+, XI.5, XII-*[nr], XII.5*[nr], XIII-*, XIII, XIII+	**11**	II--, V.5, X.5, XIV-, XVII.5, XVIII-
3	VI.5, VII--, VII-*[nr], VII+*[nr], VII.5, VIII-, XVIII, XVIII+, XVIII.5*, XIX-*[nr]	**12**	I.5
4	V--, V-*, V+, V++	**13**	IV.5, VI++, XI-, XIII.5
5	III.5, IV--, IV-*, IV*, IV+, VIII.5, IX-*, IX*, IX+, XV+, XV.5, XVI-*, XVI*, XVI+, XVI.5	**14**	I++
6	III*, III+*, III++	**16**	I+
7	II.5, III--, III-, VI--, VI-, VI, IX.5, X-, X, XIV.5, XV-**, XV	**18**	I
8	II++, VIII, VIII+, XVII-, XVII**, XVII+**	**21**	I-**
9	II, II+ IV++**, X+**, XIV, XIV+**		

Table 4.20. Categorisation of the sounds at t.s. 1 according to the lowest main partial with moderate or high detection

* moderate or lower technique feasibility; ** moderate or lower sound reliability

Lowest main partial	Locations	Lowest main partial	Locations
1	0.5, I--, I-, I	**7**	II++, II.5
2	IX*, IX+, IX.5, X-, X, X+, X.5, XI-, XI, XI+, XI.5, XII-*, XIII-*, XIII, XIII+, XIV-, XIV, XIV+, XIV.5, XV-, XV, XV+, XV.5, XVI-*	**8**	II, II+
3	VI--, VI-, VI, VI+, VI++, VI.5, VII--, VII-*, VII+*, VII.5, VIII-, VIII, VIII+, VIII.5, IX-*, XVI*, XVI+, XVI.5, XVII-, XVII, XVII+, XVII.5, XVIII-, XVIII, XVIII.5*, XIX-*	**9**	II--, II-*
4	IV*, , IV+, IV++, IV.5, V--, V-*, V+, V++, V.5	**10**	I.5
5	III+*, III++, III.5, IV--, IV-*	**11**	I++
6	III--, II-, III*	**13**	I+

Table 4.21. Categorisation of the sounds at t.s. 2 according to the lowest main partial with moderate or high reliability

$^{\mathrm{nr}}$ sounds not reliable; * moderate or lower technique feasibility; ** moderate or lower sound reliability

Lowest main partial	Locations	Lowest main partial	Locations
1	0.5$^{\mathrm{nr}}$, I--**, I-**, I	**7**	II++, II.5
2	X, X+**, X.5, XI-, XI, XI+, XI.5, XII-*$^{\mathrm{nr}}$, XIII-*$^{\mathrm{nr}}$, XIII, XIII+, XIV-, XIV, XIV+**, XIV.5	**8**	II, II+
3	VI--, VI-, VI, VI+, VI++, VI.5, VII--, VII-*$^{\mathrm{nr}}$, VII+*$^{\mathrm{nr}}$, VII.5, VIII-, VIII, VIII+, VIII.5, XVII-, XVII**, XVII+**, XVII.5, XVIII-, XVIII, XVIII.5*, XIX-*$^{\mathrm{nr}}$	**9**	II--, II-*
4	IV+, IV++**, IV.5, V--, V-*, V+, V++, V.5	**10**	I.5
5	III++, III.5, IV--, IV-*, IV*, IX-*, IX*, IX+, IX.5, X-, XV-**, XV, XV+, XV.5, XVI-*, XVI*, XVI+, XVI.5	**12**	I++
6	III--, III-, III*, III+*	**14**	I+

multiphonics and a faster tempo, as well as by an increase of the dynamics and the excitation of the string nearer the bridge, thus by an increase of the sounds' brightness. The slower tempo returns with a repetition of the end of the first part. In the following part, the darker sounds of the first part return and the patterns with female responses end progressively. The final part is, again, an electronics solo, in which the rest of the patterns end as well progressively, after which the loudspeaker's gain is decreased.

4.2.2 *Si amanece, nos vamos* for guitar

The investigation of the *tremolato* as form of articulation of the string when the the fundamental is to be constantly perceived as a pedal tone lead to a new form of multiphonics usage. The string needs to be excited near, and not very near, the bridge and touched with a very light pressure. If the string is excited very near the bridge, the fundamental is hardly perceived, because v.m. 1 and/or some of the other lower v.ms. are hardly excited due to being strongly damped, and to being excited at a small relative loop displacement. Reducing the pressure gives rise to an unbalanced sound because the fundamental is much louder than the other partials. A more balanced sound is then obtained by using a very light pressure and exciting the string near the bridge. This does not present a problem in terms of eventually not exciting a higher v.m. due to exciting the string at its closest node to the saddle, because, given the absence of amplification, only the loud partials of t.s. 1 are being taken into account (their corresponding v.ms. have larger loops, thus their closest node to the saddle is further away). There is, however, a discrepancy between the timbre of the pedal tone on the untouched string and its timbre on the touched string. This discrepancy is smaller when the untouched string string is played in *pizzicato* (i.e., the string is damped at the saddle with the side of the hand's palm). The technique of multiphonics has nevertheless to be played *normale* (i.e., non-*pizzicato*), because otherwise most main partials of the sounds are damped out. To smoothen this remaining discrepancy, the touch pressure is gradually increased (which puts in evidence the sound filtering that the technique involves), and the *pizzicato* is gradually released. To return to the sound of the untouched string, the inverse process takes place. At the usual harmonics locations, the touch pressure needs to be extremely light otherwise the higher partial is much louder (the control of the extremely light pressure is not a problem here, because the excitation of the string is continuous), for which the *pizzicato* is not released, in order to maintain the timbre of the sound of the untouched string. The tip of a plectrum is used to articulate the *tremolato*, in order to overcome the damping out of the v.ms. with smaller loops, due to the uninterrupted touching in multiphonics (decreasing the exciter width increases the excitation of these v.ms.).[151]

The score of the piece can be found in Volume 2. The introduction of the piece (bars 1-12) starts with all strings being rubbed with the hand palm, first with *tremolato* and then with accentuated short gestures, symbolising respectively the witches' broomstick flight and arrival. The string-rubbing *tremolato* is, moreover, a warning of the low-pitched *tremolato* that is yet to come. The latter is arrived at by (a)

[151] The use of the plectrum is nevertheless useful to avoid wearing out a nail.

restarting the former, (b) *cross-fading* the resulting noise with the noise of plucking the muted string 6 in light pizzicato with a side of the plectrum, and (c) unmuting the string to introduce the low-pitch. At this point, the longest section of the piece starts (section 1, bars 13-60). The plucking noise is progressively reduced by rotating the plectrum to the tip. Afterwards, the above-described process of progressively filtering/unfiltering the open-string sound takes place at the different locations (the lower feasibility of location II- is here not relevant, because only main partial 10 is of interest among those of the results). At the end of this section, the *tremolato* ends by being slightly decelerated, and then played shortly at normal speed with constant accentuation, ending on a beat (gesture 1). The transition to the next section (bars 61-65) consists in repeating gesture 1, firstly with different timbres, and then plucked at the fretboard with the string muted. In the last repetition, the *tremolato* is continued and immediately ended by a strong deceleration. The section that follows (section 2, bars 66-69) is quite contrasting: strings 5 and 6 are slowly tapped (i.e., hammered against the fretboard) with a regular rhythm, producing the interval of a tritone (the musical symbol of the devil). This gesture is repeated three times in different transpositions, being the last repetition longer. The same rhythm is then played on the muted string 6 plucked at fret X (gesture 2), which starts the transition to the end of the piece. In this transition (bars 70-73), gesture 2 is repeated two times; the second repetition is continued and accelerated to *tremolato*. The string is progressively unmuted until it is only slightly damped on the nut as in a light pizzicato. In the beginning of the last section of the piece (section 3, bars 74-80), the timbre of the lightly damped string 6 is varied by slowly moving the plucking location towards the bridge, and stopping the movement at some locations. When the hand reaches near the bridge, the hand/finger that is damping the string starts moving towards the bridge with an extremely light pressure, playing thus continuously multiphonics. The movement of the finger ends at one the locations at which multiphonics was played in section 1, and the *tremolato* ends with gesture 1. This gesture is then used at other two multiphonics locations of section 1, and in the very end of the piece on the non-damped open string, which sounds for the first time, preceded by the *tremolato* on the still damped string.

The premiere of the piece did not offer the conditions for testing it. Not only was a church not appropriate, but also there was disquiet in the audience, who was mostly in the concert to attend the performance of another player.

5 Conclusion

> In a world of electro-acoustic screeching, beeping, glitches, blips, and drones, instrumental extended techniques take on new meaning. They are employed precisely because they are instrumental. In fact, ... they capture the essence of that particular instrument, drawing out its unique timbre, its grain. These techniques are no longer an "other," disassociated from the instrument as some noise invasion. They are rather part of the sonic context of the instrument.
>
> Matthew Burtner[152]

Due to lack of colour research on the guitar, the technique of multiphonics was investigated on this instrument. It was part of a strategy of presenting non-guitarist composers with new results from the exploration of unconventional techniques. If, enticed by these results, those composers reconsider composing for guitar, a step towards overcoming the problem would be taken. Apart from theoretically scrutinising the acoustics and psychoacoustics of multiphonics, testing was carried out to determine the influence of amplification on the audibility of the weaker main components of the sounds. These results and assumptions based thereon were implemented in two musical pieces. Below, the contribution of this research and its main findings and limitations are discussed, and future work is outlined.

This is the first research of guitar multiphonics through amplification. Given the positive results, the sonorous possibilities of the amplified guitar have been extended, which may help promote the presence of the guitar in large concert halls and in large ensembles. This is also the first study that tested multiphonics with more than one player and more than two classical guitars, in order to have results that take into account the influence of the differences in guitars and players; and the first that formalised the establishment of touch locations, and based this on the facility to visually situate locations between frets – and not on the resulting sounds –, in order to reduce the uncertainty of where to touch. Moreover, different kinds of notations were suggested for the touch locations, allowing composers to chose whichever notation best suits their compositional approaches. Furthermore, a detailed explanation of the acoustics and psychoacoustics of multiphonics, which lacked in existing literature, was provided. Finally, possibly for the first time in a musical piece: (a) the amplification of the sounds of multiphonics was taken into account in the compositional process; (b) the touch pressure of multiphonics is differentiated; (c) the sounds are attained by articulating the string with *tremolato* while the touch pressure

[152] In M. Burtner, Making noise: Extended techniques after experimentalism, After Experimentalism.

is continuously increased, and are thereafter not left to ring, but disappear progressively instead, by decreasing the pressure.

The amplification with close microphone placement of most sounds of multiphonics introduces novelty to an audience, because the audience would otherwise not perceive some of the sounds' main components, regardless of room size. The main content of the sounds produced when string 6 is touched with a light to very light pressure during its excitation with a nail and a rest stroke near to very near the bridge depends mainly on the loop displacement of the v.ms. up to v.m. 29 at the touch location; however, partials 26 to 29 hardly last more than half a second, and by this point of the sounds' decay the loudness of partials higher than partial 19 is always at least 20 phon lower than the loudest main partial. The use of a *tremolato* allows to perceive faster-decaying partials with a loudness higher than when the sounds are singly excited, and to avoid a lower sound reliability.

The results, however, stem from a small sample, which is reflected in the large standard deviations of the sample's r.l. results – when using these, it should be borne in mind that one may be presented with much better or much worse situations. Moreover, the results may not be valid for all listeners because the data evaluation took psychoacoustics only theoretically into account, that is, perception tests were not carried out. Furthermore, some partials may only be perceivable for a period of time shorter than 0.5 s when a microphone model of a lower sensitivity is used, or may be emphasised by a directional microphone, which is preferable in a concert situation; other partials may be perceived softer because partial masking was not taken into account, and because the l.m.p. was always considered to have a 40 phon loudness, independent of its mode number. Finally, the proposed approach for the establishment of locations deprives the composer (or improviser) of the freedom to choose the exact sound he would like to hear. However, it assures him that what he notates for the execution is closer to the expected result, thereby avoiding frustration and optimising rehearsal time. The guitarist avoids the stress of microtonally memorising the touch location on the string and the possible frustration of not having produced the required sound.

The work carried out for this thesis is the first step of a vaster investigation on guitar multiphonics. Future work includes:

- Testing the musical compositions in concert.
- Comparing the experimental results with those (not yet) obtained with the same method from (a) simultaneous recordings with microphones of different sensitivity and/or with a cardioid pick-up pattern made during the experiment; and (b) recordings on strings 4 and 5 made during the recording sessions;

and drawing conclusions about, among others, microphone type and placement.

- Finding for each main partial on each string a correlation between its r.l. category at a location, the r.d. from the location of its corresponding v.m., and the mode number of the l.m.p. This would allow to predict (for the playing conditions of the experiment) the r.l. category of the main partials of the sounds at any touch location, as well as the feasibility of the technique and the reliability of the sounds.
- Conveying the results to the artistic community, mentioning situations better and worse than the average. Not all members of this community are familiar with the scientific language, for which it is necessary to transmit the results in a language that suits them. A digital publication would allow searching for the production conditions that give rise to a certain sound, or vice-versa, and finding sounds of a certain category and organising them according to different attributes; in an online publication the information would be always updated and freely available for all.
- Asking other composers to implement the results, and testing the implementations with various guitarists and, if possible, in more than one room and with more than one amplification hardware model.

This research has shown that the technique of multiphonics is a valuable tool for composers looking for a sound world alternative to the guitar's paradigmatic and acoustically limited sound. The components of the sounds of multiphonics combine with a different chemistry, which gives them quite a distinct colour that is only completely revealed through amplification. The technique finds then adequacy in the different instrument the guitar turns into through amplification.

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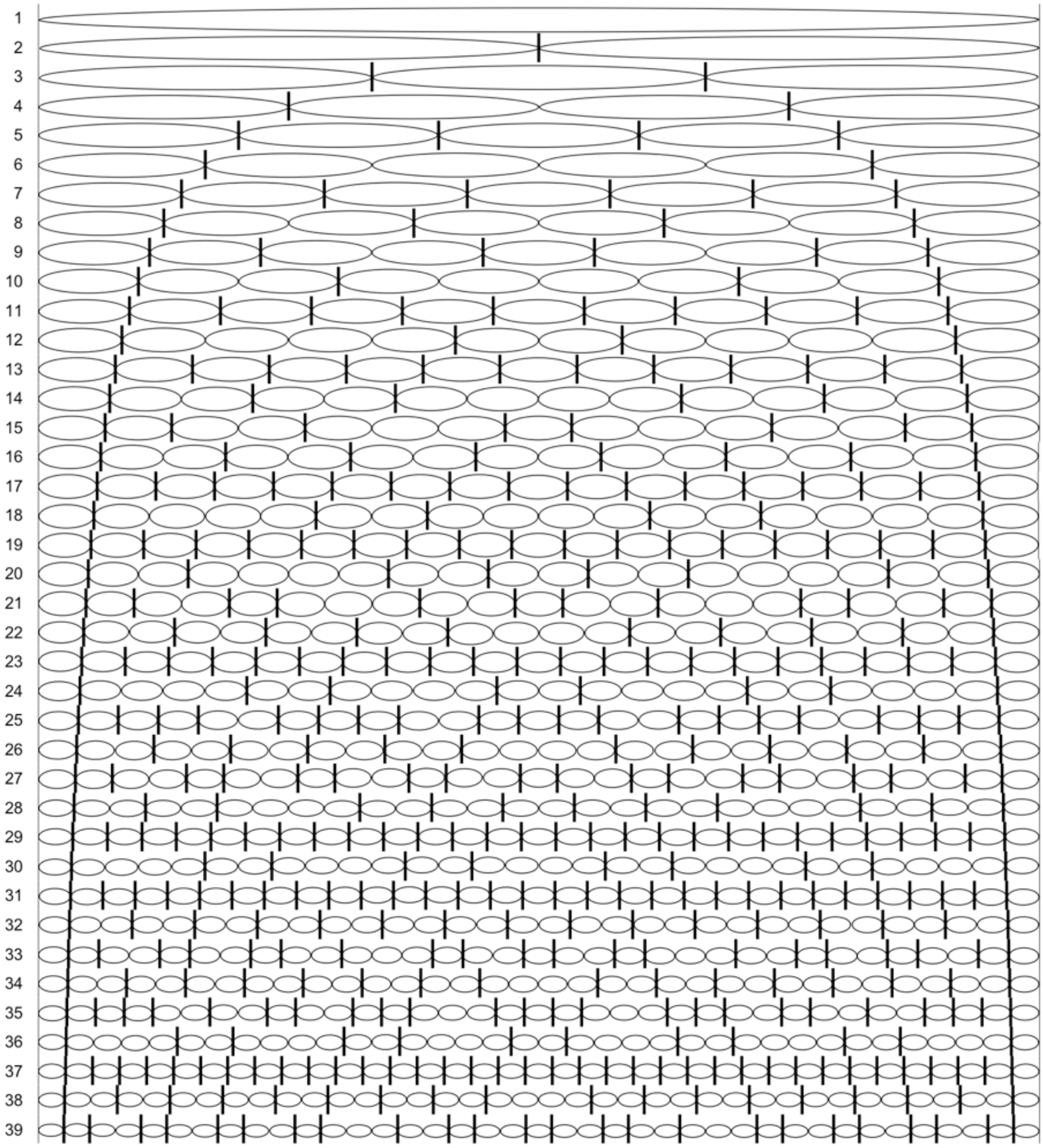
Appendices

Appendix A – Main nodes of vibrational nodes 1 to 39 of a string

Graphical representation (in juxtaposition) of the first 39 vibrational modes of a string. The main nodes of each vibrational mode (i.e., the nodes, at which the vibrational node is the lowest v.m. sharing the node) are marked with a vertical line. Differences in excitation strengths are not accounted for.



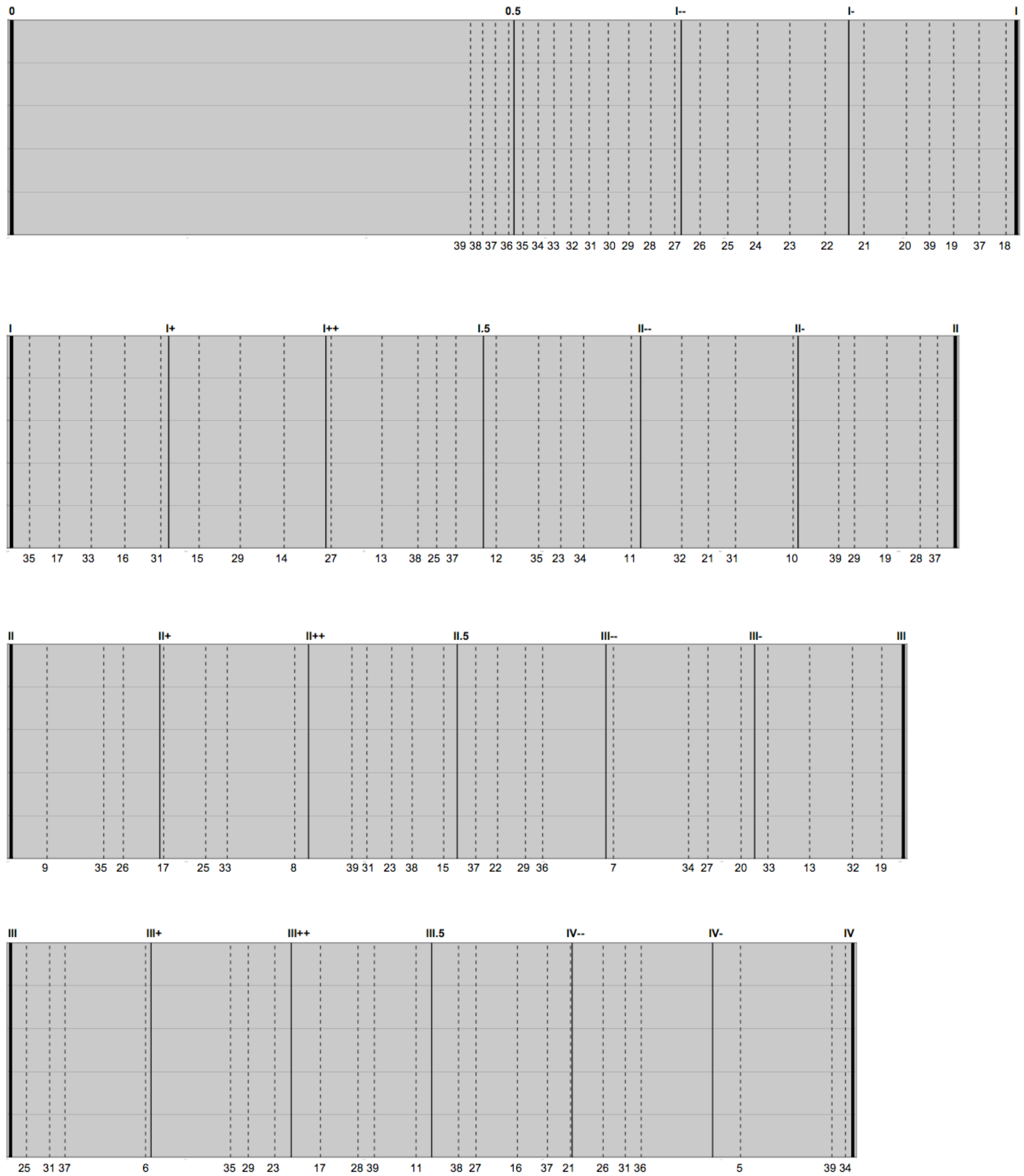
Appendix B – Relative distance (%) from each touch location of the closest main node of each vibrational mode

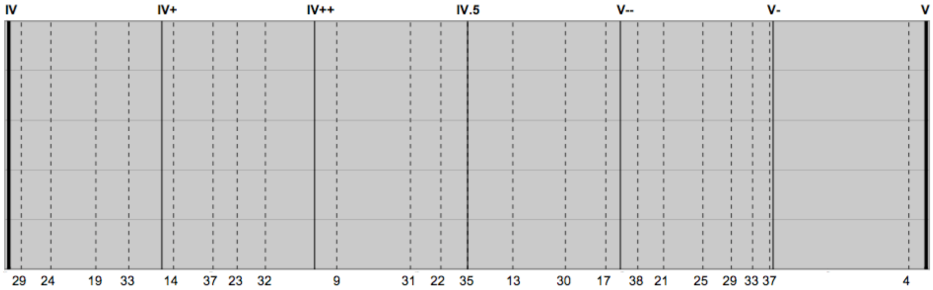
A negative value means the node is situated between the nut and the touch location, and a positive value means the node is situated between the touch location and the saddle. Values of cells in light grey background are smaller than 20%. When the value is typed in bold, the node is at its smallest r.d. from the location. A black background of a location's ID flags type A locations, whereas a dark grey background flags type B locations.

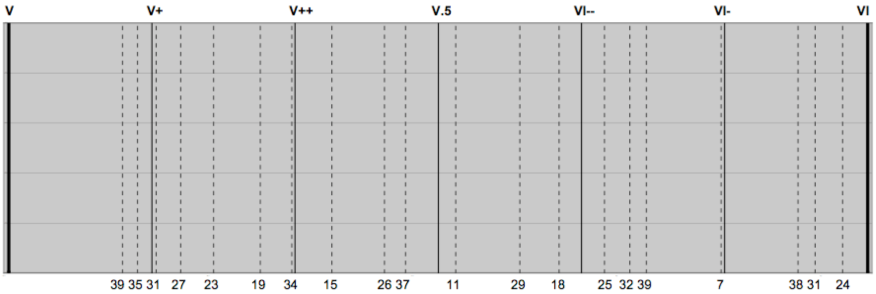
loc./p.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	loc./p.
0.5	-3																	49	47	44	41	38	35	33	30	27	24	21	19	16	13	10	7	5	2	-1	-4	-7	-9	0.5
I--	-4											-45	-49	48	44	40	36	33	29	25	21	18	14	10	6	3	-1	-5	-9	-12	-16	-20	-23	-27	-31	-35	-38	-42	-46	I--
I-	-5										49	44	39	35	30	25	20	16	11	6	2	-3	-8	-12	-17	-22	-26	-31	-36	-40	-45	-50	46		36		27		18	I-
I	-6								49	44	38	33	27	21	16	10	5	-1	-7	-12	-18	-23	-29	-35	-40	-46	48		37		26		15		4		-8		-19	I
I+	-6							48	42	35	29	22	16	9	3	-4	-10	-17	-23	-30	-36	-43	-49		38		25		12		-1		-14		-27		-40			I+
I++	-7						48	41	34	26	19	11	4	-3	-11	-18	-25	-33	-40	-48	45		30		16		1		-14		-29		-43	49	42		27	20		I++
I.5	-8						42	34	26	17	9	1	-7	-16	-24	-32	-40	-49	43		27		10		-7		-23		-40		44	36		19	11		-6	-14		I.5
II--	-9					45	36	27	18	9	-1	-10	-19	-28	-37	-46	45		26		8		-10		-29		-47	44	35		17	7		-11	-20		-38	-47	43	II--
II-	-10					40	30	20	10	0	-10	-20	-30	-40	50		30		9		-11		-31		49	39		19	9		-11	-21		-41	49		29		9	II-
II	-11				45	35	24	13	2	-9	-20	-31	-42		36		15		-7		-29		49		27	16		-5	-16		-38	-49	40		18		-4		-25	II
II+	-12				41	30	18	6	-6	-17	-29	-41	47		24		0		-23		-47	42	30		6	-5		-29	-41		36		12		-11		-35		42	II+
II++	-13				37	25	12	-1	-13	-26	-38		37		11		-14		-39	48		23	11		-14	-27			35		10		-15		-40	47	35	22	10	II++
II.5	-13			46	33	20	6	-7	-21	-34	-48		26		-1		-28		45	32		5	-8		-35	-49	38		11		-16		-43	44		17	4	-10	-23	II.5
III--	-14			43	29	15	0	-14	-28	-42	43		15		-14		-42		29	15		-13	-28		44		15		-13		-42	44	30	16		-13	-27	-41		III--
III-	-15			40	25	10	-6	-21	-36		34		4		-26		44		14	-2		-32	-47		23		-7		-37		33	18	2	-13		-43	42			III-
III	-16			36	20	5	-11	-27	-43		25		-7		-39	45	30		-2	-18			34		2		-30		39		7	-9	-25	-41	43		11			III
III+	-17			33	17	0	-17	-34	50		16		-17		-50	33	16		-17	-34	49		16		-17		49	32	16		-18	-34			16		-18		49	III+
III++	-17		48	30	13	-5	-22	-40	43		8		-27			20	3		-32	-50	33		-2		-37	45	28	10	-7		-42				-12		-47	36	18	III++
III.5	-18		45	27	9	-10	-28	-46	36		-1		-38	44		8	-11		-47		16		-20			25	7	-12	-30		34				-39	42	24	6	-13	III.5
IV--	-19		43	24	5	-14	-33		28		-10		-48	33		-5	-24		38		0		-38	43		5	-15	-34	47		9					14	-5	-24	-43	IV--
IV-	-20		40	21	1	-19	-39		21		-18		42	22		-17	-37		23		-17		44	24		-16	-36		25		-15		45	25		-14	-34		26	IV-
IV	-21		38	17	-3	-24	-44		14		-27		32	11		-30	49		8		-33	46	26	5		-36			2		-40	40	19	-1		-43	37		-5	IV
IV+	-21		36	15	-7	-28	-50		8		-35		22	1		-42	37		-6		-49	30	8	-13					-20		37	16	-5	-27			9		-34	IV+
IV++	-22		34	12	-11	-33	45		1		-43		13	-10			24		-20		36	13	-9	-31	47				-41	37	14	-8	-30		26		-18			IV++
IV.5	-23		31	9	-14	-37	40		-6		49		3	-20			11		-34		20	-3	-26	-49	29				37	14	-9	-31	46		0		-46	31		IV.5
V--	-24		29	6	-18	-42	35		-12		40		-7	-30	46		-1		-48		4	-19	-43		10				16	-8	-32		21		-26		27	3		V--
V-	-24		27	3	-22	-46	30		-19		32		-16	-41	35		-14		37		-11	-36	40		-9		43		-6	-30	45		-3		48		-1	-25		V-
V	-25		25	0	-25		24		-26	49	24		-26		24		-26	48	23		-27		23		-27	48	23		-27		22		-28	47	22		-28		22	V
V+	-26	48	23	-3	-29		20		-32	42	16		-35		13		-38	36	10		-41		7		-45	30	4		-48		1			23	-2		46		-6	V+
V++	-26	47	21	-6	-32		15		-38	35	9		-44		3		50	23	-3				-9		38	11	-15		32		-21			-1	-27		20		-33	V++
V.5	-27	46	18	-9	-36		10		-45	28	1		47		-8		38	11	-17				-25	48	20	-7	-34		12		-43	30		-24			-6		40	V.5
VI--	-28	44	16	-12	-39		5			21	-7		37		-18		26	-2	-30				-41	31	3	-25	47		-9		35	8		-48			-32	40	12	VI--
VI-	-29	43	14	-14	-43		0			14	-14		28		-29	43	14	-15	-43				42	14	-15	-43	28		-29		14	-15					42	14	-15	VI-
VI	-29	41	12	-17	-46		-5			7	-22		19		-39	31	2	-27	44				26	-3	-32		9		-49		-8	-37	33			46	16	-13	-42	VI
VI+	-30	40	10	-20	-50		-10			0	-29		11		-49	21	-9	-39	31			41	11	-19	-49		-9		31		-28		12			22	-8	-38		VI+
VI++	-31	39	8	-22	47		-14			-6	-37		2			10	-20		18			27	-4	-35	35		-27	43	12		-49		-10		29	-2	-33			VI++
VI.5	-31	37	6	-25	44		-19	50		-13	-44		-7			0	-32		6			12	-19		18		-44	24	-7		31		-32	37	5	-26	43			VI.5
VII--	-32	36	4	-28	40		-24	45		-19	49		-15			-11	-43		-7			-3	-35		2			6	-26		10			14	-18	-50	18			VII--
VII-	-33	35	2	-30	37		-28	39		-26	41		-24	44		-22	46		-19	48		-17	-50		-15			-13	-45		-10			-8	-41		-6			VII-
VII	-33	33	0	-33	34		-33	34		-33	34		-32	34		-32	35		-32	35		-32	35		-31	35		-31	36		-31	36		-31	36		-31	36		VII
VII+	-34	32	-3	-37	29		-39	26		-42	24		-45	21		-47	19		-50	16			14		45	11			8		40	6			3		35	1		VII+
VII.5	-35	30	-5	-41	24		-46	19			14		43	8			3		33	-3			-8		22	-13			-19	46	11	-24			-30	35	0	-35	30	VII.5
VIII-	-36	28	-8	-44	20		48	11			3		31	-5			-13		15	-21	43		-30		-2	-38	26		-46	18	-18				38	2	-34		-7	VIII-
VIII	-37	26	-11	-48	15		41	4			-7		19	-18			-29	34	-3	-40	23		49		-25		1		27	-10	-47			42	5	-32	31		-43	VIII
VIII+	-38	24	-14		11		35	-3			-17	45	7	-30			-44	18	-20		4		29		-47		-23	39	1	-37	25		50	12	-26		-2			VIII+
VIII.5	-39	22	-16		6		29	-10			-26	35	-4	-43			41	2	-37		-14	47	8				-47	14	-24		-2		21	-18			-35	27		VIII.5
IX-	-40	21	-19		2		22	-17	43		-36	24	-16				26	-14	47		-33	28	-12				29	-10	50		-29	31	-9	-48			33	-7		IX-
IX	-41	19	-22		-3		16	-24	35		-46	14	-27				11	-30	30			8	-32			46	5	-35	24		43	3	-38				0	-41	19	IX
IX+	-41	17	-24		-7		10	-31	28		45	4	-38			38	-3	-45	14			-10	48			24	-17		0		17	-24	35				-31		-14	IX+
IX.5	-42	16	-27		-11		5	-38	20		36	-6	-49			25	-18		-2			-29	29		45	3	-40		-24	34	-8		7				38		-46	IX.5
X-	-43	14	-29		-15		-1	-44	13		27	-17	40			11	-32		-18	39		-47	10		24	-19			-48	9	-34		-20	37			7		21	X-
X	-44	12	-32		-19		-7		5		17	-27	30		42	-2	-46		-34	22			-9	47	3	-41			28	-16	40		-48	8			-23	33	-11	X
X+	-45	11	-34		-23		-13		-2		9	-36	19		30	-15	41		-49	7			-27	28	-17			49	5	-40	15			-19	37		47	3	-42	X+
X.5	-45	9	-36		-27		-18		-9		0	-45	9		18	-27	27		36	-9	46		-45	9	-36			27	-18		-9	46		-45	9		18	-27		X.5
XI-	-46	8	-39		-31		-24		-16		-9		-1		6	-40	14		21	-25	29		36	-10	44			5	-41		-33	20			-18	35	-11			XI-
XI	-47	6	-41		-35		-29		-23		-17		-11		-5		1		6	-41	12		18	-29	24		30	-17	36		42	-5	48		-46	7	-40			XI
XI+	-48	4	-43		-39		-34		-30		-25		-21		-17		-12		-8		-3		1	-46	6		10	-38	15		19	-29	24		28	-20	33		37	XI+
XI.5	-49	3	-46		-43		-40		-37		-34		-31		-28		-25		-22		-19		-16		-13		-10		-7		-4		-1		2	-46	5		8	XI.5
XII-	-49	1	-48		-46		-45		-43		-42		-40		-39		-37		-36		-34		-33		-31		-30		-28		-27		-25		-24		-22		-21	XII-
XII	-50	0	-50		-50		-50		-50		-50		-50		-50		-50		-50		-50		-50		-50		-50		-50		-50		-50		-50		-50		-50	XII
XII+	49	-1	48		46		45		44		42		41		39		38		37		35		34		32		31		30		28		27		25		24		23	XII+
XII.5	49	-3	46		43		40		37		35		32		29		26		23		21		18		15		12		9		7		4		1	49	-2		-5	XII.5
XIII-	48	-4	44		39		35		31		27		23		18		14		10		6		2	49	-3		-7	41	-11		-15	33	-19		-24	24	-28		-32	XIII-
XIII	47	-6	42		36		30		25		19		14		8		2		-3	44	-9		-15	33	-20		-26	21	-31		-37	10	-43		-48	-1	46			XIII
XIII+	47	-7	40		33		26		19		12		5		-2	45	-9		-16	31	-23		-30	17	-37		-44	3	49		42	-11			29	-25	22			XIII+
XIII.5	46	-8	38		29		21		13		5		-4		-12	34	-20		-28	17	-37		-45	1	47			-16	30		22	-32			5	-49	-3	43		XIII.5
XIV-	45	-10	36		26		16		7		-3	42	-12		-22	23	-31		-41	4			40	-15	30			-34	11		1			37	-18		-27	18		XIV-
XIV	45	-11	34		23		12		1		-10	35	-21		-32	13	-43		46	-9			25	-31	14				-8	36	-19			15	-41		48	-7	37	XIV
XIV+	44	-12	32		20		7		-5		-17	27	-29		-41	3	47		34	-22			10	-46	-2	42			-26	18	-38		49	-7			25	-31	13	XIV+
XIV.5	43	-13	30		16		3	46	-10		-24	20	-37			-7	36		23	-34			-4		-18	26			-44	-1	42		29	-28			2		-11	XIV.5
XV-	43	-15	28		13		-1	41	-16		-31	12	-45			-17	25		11	-47		39	-19		-33	9			37	-20	23		8	-49			-21		-36	XV-
XV	42	-16	26		10		-6	36	-22		-38	5	47			-27	15		-1			25	-33		-49	-7	35		19	-39	3	45	-13				-44		40	XV
XV+	41	-17	24		7		-10	32	-27		-44	-3	39			-37	5	46	-12			12	-47			-22	19		2		-15	27	-32				34		17	XV+
XV.5	41	-18	23		4		-14	27	-32		50	-10	31			-46	-5	36	-24			-1	40			-38	3	44	-15		-33	8	49				12		-6	XV.5
XVI-	40	-19	21		1		-18	22	-38		43	-17	24				-15	25	-35		46	-14	26				-13	28	-32		49	-11	29				-10	30	-29	XVI-
XVI	40	-21	19		-2		-22	17	-43		37	-24	16				-25	14	-46		33	-27	13				-29	11	-49		30	-30	10	49			-32	8		XVI
XVI+	39	-22	17		-4		-26	13	-48		30	-30	9	48			-35	4	43		22	-39	0				-44	-4	35		13	-48	-9	30			48	-13		XVI+
XVI.5	39	-23	16		-7		-30	9			24	-37	1	40			-44	-6	33		10		-13				41	-20	19		-4		-27	11	50		27	-34		XVI.5
XVII-	38	-24	14		-10		-34	4			18	-44	-6	32			46	-16	22		-2		-26				26	-36	2	40	-22		-46	-8	31		7			XVII-
XVII	37	-25	12		-13		-38	0			12		-13	24			37	-26	12	49	-13		-38		36		11		-14	24	-39			-26	11	48	-14			XVII
XVII+	37	-26	11	48	-15		-41	-5			6		-20	17			28	-35	2	39	-24		49		23		-3		-29	8	45			-44	-7	30	-34		40	XVII+
XVII.5	36	-27	9	46	-18		-45	-9			0		-27	10			19	-45	-8	28	-35		37		10	47	-17		-44	-8	29				-26	11	47		20	XVII.5
XVIII-	36	-28	8	44	-21		-49	-13			-5		-34	2			10		-18	18	-47		25		-3	33	-31		41	-24	12	48			-44	-8	28		-1	XVIII-
XVIII	35	-29	6	41	-23		47	-17			-11		-40	-5			1		-28	7			13		-16	19	-45		25	-39	-4	31			37	-27	8	44	-21	XVIII
XVIII+	35	-30	5	39	-26		44	-21		49	-17		-47	-12			-7		-38	-3			2		-29	6			11		-19	15			20	-45	-10	25	-40	XVIII+
XVIII.5	34	-31	3	37	-28		41	-25		44	-22		47	-19			-16		-47	-13			-10		-41	-7			-3		-35	0			3		-29	6		XVIII.5
XIX-	34	-32	2	35	-31		37	-29		39	-27		40	-26		42	-24		43	-23		45	-21		47	-19		48	-18		-50	-16			-15		-47	-13		XIX-
XIX	33	-33	0	33	-33		34	-33		34	-33		34	-33		34	-33		34	-33		34	-32		34	-32		34	-32		35	-32		35	-32		35	-32		XIX
loc./p.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	loc./p.

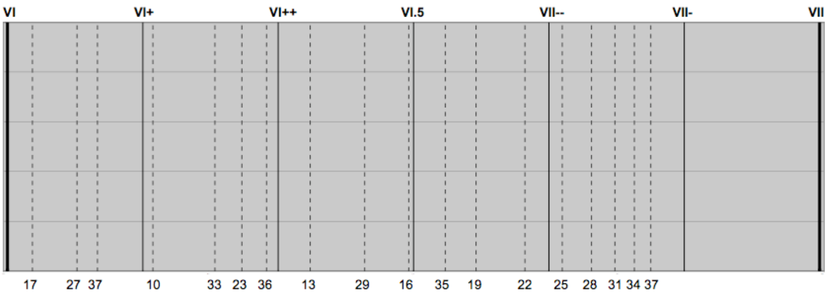
Appendix C – Virtual frets and main nodes of each vibrational mode from the nut to fret XIX

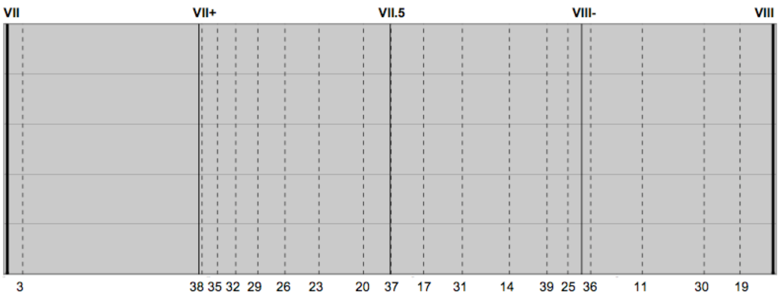
Graphical representation of the position on the fretboard of the virtual frets (solid lines) and of the main nodes of each v.m. up to v.m. 39 (dashed lines). Above, in roman numerals: frets/v.fs.' initial nomenclature; below, in arabic numerals: number of the lowest v.m. sharing that node. Fret-length proportionality is maintained.

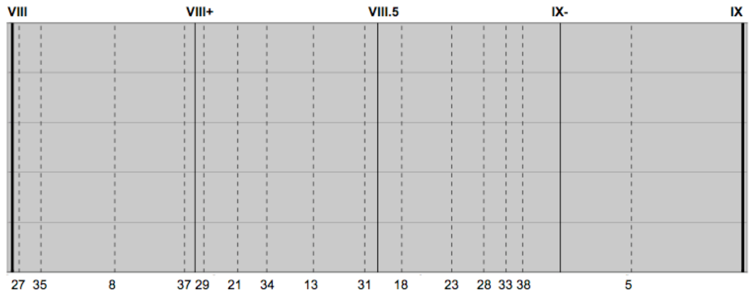


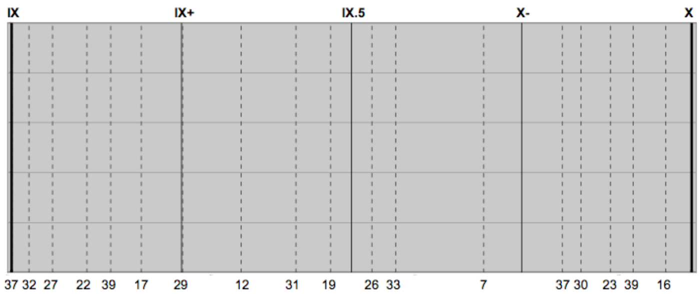

IV
IV+
IV++
IV.5
V--
V-
V
29 24 19 33 14 37 23 32 9 31 22 35 13 30 17 38 21 25 29 33 37 4

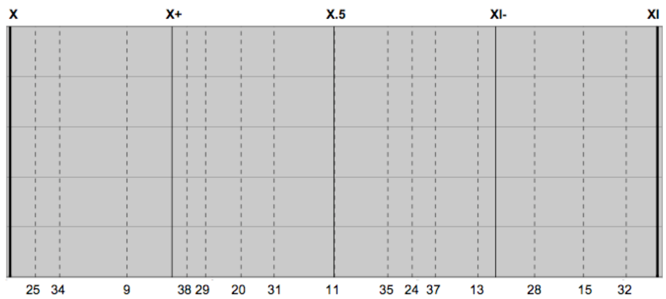

V
V+
V++
V.5
VI--
VI-
VI
39 35 31 27 23 19 34 15 26 37 11 29 18 25 32 39 7 38 31 24

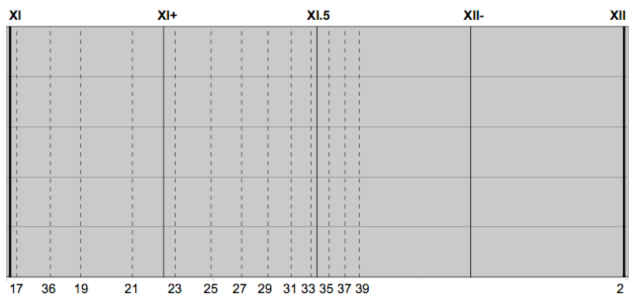

VI
VI+
VI++
VI.5
VII--
VII-
VII
17 27 37 10 33 23 36 13 29 16 35 19 22 25 28 31 34 37

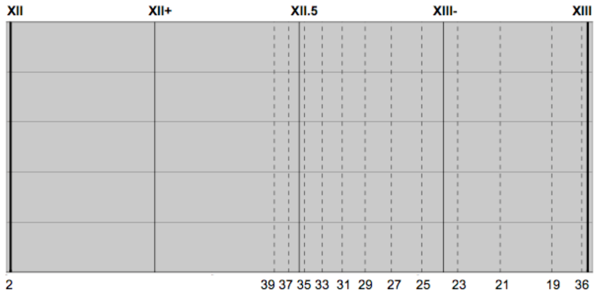

VII
VII+
VII.5
VIII-
VIII
3 38 35 32 29 26 23 20 37 17 31 14 39 25 36 11 30 19

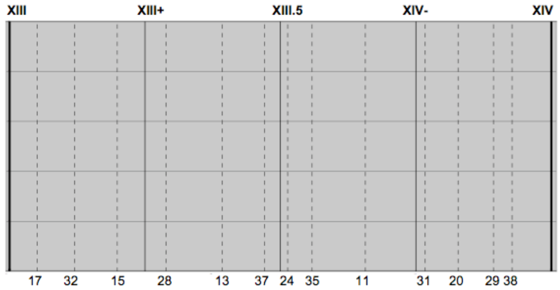

VIII VIII+ VIII.5 IX- IX
27 35 8 37 29 21 34 13 31 18 23 28 33 38 5

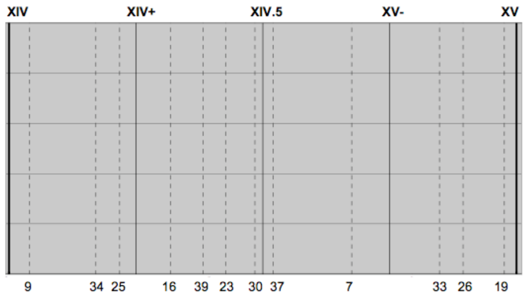

IX IX+ IX.5 X- X
37 32 27 22 39 17 29 12 31 19 26 33 7 37 30 23 39 16

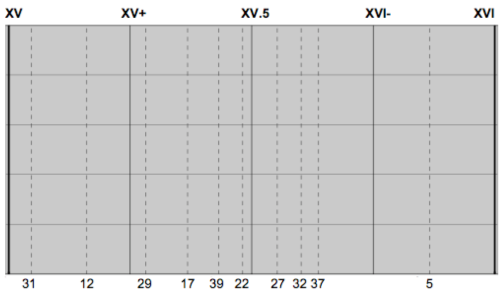

X X+ X.5 XI- XI
25 34 9 38 29 20 31 11 35 24 37 13 28 15 32

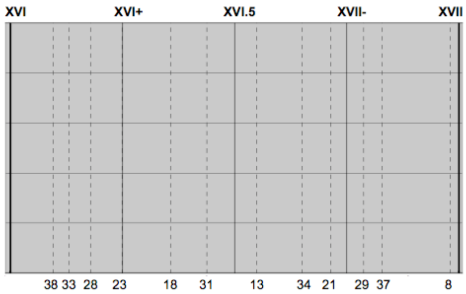

XI XI+ XI.5 XII- XII
17 36 19 21 23 25 27 29 31 33 35 37 39 2

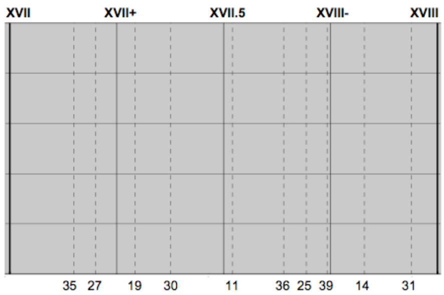

XII
XII+
XII.5
XIII-
XIII
2
39 37 35 33 31 29 27 25 23 21 19 36

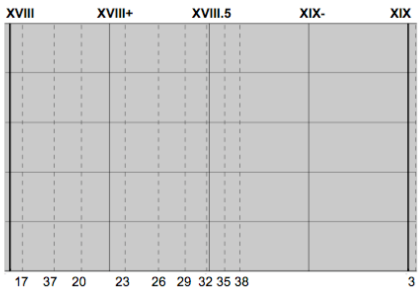

XIII
XIII+
XIII.5
XIV-
XIV
17 32 15 28 13 37 24 35 11 31 20 29 38


XIV
XIV+
XIV.5
XV-
XV
9 34 25 16 39 23 30 37 7 33 26 19


XV
XV+
XV.5
XVI-
XVI
31 12 29 17 39 22 27 32 37 5


XVI XVI+ XVI.5 XVII- XVII
38 33 28 23 18 31 13 34 21 29 37 8


XVII XVII+ XVII.5 XVIII- XVIII
35 27 19 30 11 36 25 39 14 31

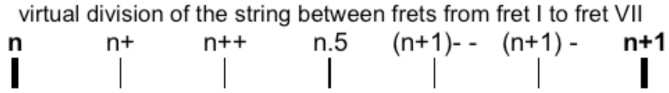

XVIII XVIII+ XVIII.5 XIX- XIX
17 37 20 23 26 29 32 35 38 3

Appendix D – Playing instructions of the experiment

Reproduction of the playing instructions supplied to the guitarists prior to the recording sessions. Note: situation B was not recorded, and all takes lasted 1 s.

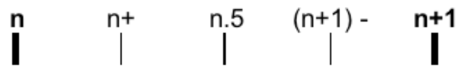
Until fret VII, the lenght of the string between two frets was virtually divided in six parts. There are then five virtual frets:

virtual division of the string between frets from fret I to fret VII



From fret VII to fret XIX, the division is in four parts, there being three virtual frets:

virtual division of the string between frets from fret VII to fret XIX



The harmonic content of the sound resulting from touching the string at each fret and virtual fret of the wounded bass strings were first theoretically predicted and then experimented on the guitar by the author. The results were put in a chart that was not given to the guitarists in order for them to play the sounds based on the location and not on the harmonic content predicted.

The sounds will be recorded having the concert situation present. From the guitarists' side, this implies for example, having practised the execution of the multiphonics before and having a similar aging of the strings as in a concert. Regarding the amplification, it implies using microphones adequate for that situation.

The feasiblility of the sounds in the case where there is no time to prepare the position, will also be determined.

Recording procedure and playing instructions

The harmonics/multiphonics of each of the wounded bass strings will be recorded in one take starting from the lowest location. Three takes of two different situations will be recorded:

A. after plucking maintain the left hand near the fingerboard and take time to prepare the next location
B. after damping the sound move the left hand away from the fingerboard and play the following without preparation (also visually)

For each location:

1. say the location name and wait 0,5 sec before playing
2. when playing:
    a. mute all other strings (for example with the touching finger)
    b. pluck the near the bridge (to ensure the presence of all possible components) with *apoyando* stroke, *forte*
    c. touch with minimum pressure (to ensure the maximum vibration amplitude of the components). Take as reference pressure the one from which, in the 5th harmonic at IV- when starting from zero pressure, the first harmonic is not present in the decay any more.
    d. touch during a short time (to ensure the longest duration of the components) but maintain the other two wounded bass strings strings muted.
3. let it sound:
    take 1 of A: until vibration dies
    all other takes: for ca. 1 second
4. wait 0,5 sec before playing the following

Locations list

H = isolated harmonic (when pressure >= reference pressure)

	0.5		V++	(H)	XII-
	I--		V.5	H	XII
	I-		VI--	(H)	XII+
	I		VI-		XII.5
	I+		VI		XIII-
	I++		VI+		XIII
	I.5		VI++		XIII+
	II--		VI.5		XIII.5
	II-		VII--		XIV-
	II	(H)	VII-		XIV+
	II+	H	VII		XIV.5
	II++	(H)	VII+		XV-
	II.5		VII.5		XV+
	III--		VIII-		XV
	III-		VIII		XV.5
	III		VIII+	H	XVI-
	III+		VIII.5		XVI
	III++	H	IX-		XVI+
	III.5		IX		XVI.5
	IV--		IX+		XVII-
H	IV-		IX.5		XVII
	IV		X-		XVII+
	IV+		X		XVII.5
	IV++		X+		XVIII-
	IV.5		X.5		XVIII
	V--		XI-		XVIII+
	V-		XI		XVIII.5
H	V		XI+	(H)	XIX-
	V+		XI.5	H	XIX

Appendix E – Feasibility of multiphonics and reliability of the sounds

Regarding the feasibility of the technique, a “1” means the guitarist played successfully multiphonics right after the attack, and a “0” the contrary. In regard to the reliability of the sounds, a “1” means the guitarist produced reliable sounds, and a “0” the contrary. A black background of a location's ID flags type A locations, whereas a dark grey background flags type B locations.

	Feasibility						Reliability					
Loc.	**Sample**	**G1**	**G2**	**G3**	**G4**	**G5**	**Sample**	**G1**	**G2**	**G3**	**G4**	**G5**
0.5	high	1	1	1	1	1	not reliable	-	-	-	-	-
I--	high	1	1	1	1	1	moderate	1	1	1	0	0
I-	high	1	1	1	1	1	moderate	1	1	1	0	0
I	high	1	1	1	1	1	high	1	1	1	1	0
I+	high	1	1	1	1	1	high	1	0	1	1	1
I++	high	1	1	1	1	1	high	1	1	1	1	0
I.5	high	1	1	1	1	1	high	1	1	1	1	1
II--	high	1	1	1	1	1	high	1	1	1	1	0
II-	low	1	0	0	0	1	high	1	1	1	1	0
II	high	1	1	1	1	1	high	1	1	1	0	1
II+	high	1	1	1	1	1	high	1	1	1	1	1
II++	high	1	0	1	1	1	high	1	1	1	1	0
II.5	high	1	1	1	1	1	high	1	1	1	1	1
III--	high	1	1	1	0	1	high	1	1	1	1	1
III-	high	1	1	1	1	1	high	1	1	1	1	1
III	moderate	1	0	0	1	1	high	1	1	1	1	1
III+	moderate	1	0	1	0	1	high	1	1	1	1	1
III++	high	1	0	1	1	1	high	1	1	1	1	1
III.5	high	1	1	1	1	1	high	1	1	1	1	1
IV--	high	1	1	1	0	1	high	1	1	1	1	1
IV-	very low	1	0	0	0	0	high	1	1	1	1	1
IV	moderate	1	0	1	0	1	high	1	1	1	1	1
IV+	high	1	1	1	1	1	high	1	1	1	1	1
IV++	high	1	1	1	1	1	moderate	1	0	1	1	0
IV.5	high	1	1	1	1	1	high	1	1	1	1	1
V--	high	1	1	1	1	1	high	1	1	1	1	1
V-	low	1	0	0	0	1	high	1	1	1	1	1
V	not feasible	-	-	-	-	-	0	-	-	-	-	-
V+	high	1	0	1	1	1	high	1	1	1	1	0
V++	high	1	1	1	1	1	high	1	1	1	1	0
V.5	high	1	1	1	1	1	high	1	1	1	1	1
VI--	high	1	1	1	1	1	high	1	1	1	1	1
VI-	high	1	1	1	1	1	high	1	1	0	1	1
VI	high	1	1	1	1	1	high	1	1	1	1	1
VI+	high	1	x	1	1	1	high	1	x	1	1	1
VI++	high	1	x	1	1	1	high	1	x	1	0	1
VI.5	high	1	1	1	1	1	high	1	1	1	1	1
VII--	high	1	x	0	1	1	high	1	x	1	1	1
VII-	low	1	x	0	0	0	not reliable	-	x	-	-	-
VII	not feasible	-	-	-	-	-	-	-	-	-	-	-
VII+	low	1	0	0	0	x	not reliable	-	-	-	-	x
VII.5	high	1	1	0	1	1	high	1	1	1	1	1
VIII-	high	1	1	1	1	1	high	1	1	0	1	1
VIII	high	1	1	1	1	1	high	1	1	1	1	1

	Feasibility						Reliability					
Loc.	**Sample**	**G1**	**G2**	**G3**	**G4**	**G5**	**Sample**	**G1**	**G2**	**G3**	**G4**	**G5**
VIII+	high	1	0	1	1	1	high	1	1	1	1	0
VIII.5	high	1	1	1	1	1	high	1	1	1	1	1
IX-	low	1	0	0	0	1	high	1	1	1	1	0
IX	moderate	1	0	0	1	1	high	1	1	1	1	1
IX+	high	1	0	1	1	1	high	1	1	1	1	0
IX.5	high	1	1	1	1	1	high	1	1	1	1	0
X-	high	1	1	1	1	1	high	1	1	1	1	1
X	high	1	1	1	1	1	high	1	1	1	1	1
X+	high	1	1	1	1	1	moderate	1	1	1	0	0
X.5	high	1	1	1	1	1	high	1	1	1	1	0
XI-	high	1	1	1	1	0	high	1	1	1	1	1
XI	high	1	1	1	1	1	high	1	1	1	0	1
XI+	high	1	1	1	1	1	high	1	1	1	1	0
XI.5	high	1	1	1	0	1	high	1	1	1	1	0
XII-	low	1	0	0	0	1	not reliable	-	-	-	-	-
XII	not feasible	-	-	-	-	-	-	-	-	-	-	-
XII+	not feasible	0	0	0	0	0	-	-	-	-	-	-
XII.5	moderate	1	0	0	1	1	not reliable	-	-	-	-	-
XIII-	moderate	1	0	0	1	1	high	1	1	1	1	1
XIII	high	1	0	1	1	1	high	1	1	1	1	0
XIII+	high	1	1	1	1	1	high	1	1	1	1	0
XIII.5	high	1	1	1	1	0	high	1	1	1	1	1
XIV-	high	1	1	1	1	1	high	1	1	1	1	0
XIV	high	1	1	1	1	1	high	1	1	1	1	0
XIV+	high	1	1	1	1	1	low	1	1	0	0	0
XIV.5	high	1	1	1	1	1	high	1	1	1	1	0
XV-	high	1	1	1	0	1	moderate	1	1	0	1	0
XV	high	1	1	1	1	1	high	1	1	1	1	0
XV+	high	1	0	1	1	1	high	1	1	1	1	0
XV.5	high	1	0	1	1	1	high	1	1	1	1	0
XVI-	very low	1	0	0	0	0	high	1	1	1	1	1
XVI	low	1	0	0	0	1	high	1	1	1	1	1
XVI+	high	1	0	1	1	1	high	1	1	1	1	1
XVI.5	high	1	1	1	1	1	high	1	1	1	1	1
XVII-	high	1	1	1	1	1	high	1	1	1	1	1
XVII	high	1	0	1	1	1	moderate	1	1	0	1	0
XVII+	high	1	1	1	1	1	moderate	1	1	0	1	1
XVII.5	high	1	1	1	1	1	high	1	1	1	1	0
XVIII-	high	1	1	1	1	1	high	1	1	1	1	1
XVIII	high	1	1	1	1	1	high	1	1	1	1	0
XVIII+	high	1	1	1	1	1	high	1	1	1	1	0
XVIII.5	moderate	1	1	0	1	0	high	1	1	1	1	-
XIX-	very low	1	0	0	0	0	not reliable	-	-	-	-	-
XIX	not feasible	-	-	-	-	-	-	-	-	-	-	-

Appendix F – Detection degree in t.s. 1 of the main partials at each location

The values in each cell are the r.d. values of Appendix B. When the value is typed in bold, the node is at its smallest r.d. from the location. A black background of a location's ID flags type A locations, whereas a dark grey background flags type B locations. The correspondence between the formatting of the values and cells and the detection degree of the partials is the following:

- black background – high detection
- grey background – moderate detection
- white background, values typed in black – low detection
- white background, values typed in grey – very low detection
- cross – not detected

loc./p.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	loc./p.
0.5	-3																												19	16	13	10	7	5	2	-1	-4	-7	x	0.5
I--	-4																					18	14	10	6	3	-1	-5	-9	-12	-16									I--
I-	-5																	16	11	6	2	-3	-8	-12	-17														x	I-
I	-6														16	10	5	-1	-7	-12	-18												15		4		-8		x	I
I+	-6												16	9	3	-4	-10	-17											12		-1		-14							I+
I++	-7										19	11	4	-3	-11	-18									16		1		-14											I++
I.5	-8									17	9	1	-7	-16									10		-7									19	11		-6	-14		I.5
II--	-9								18	9	-1	-10	-19								8		-10								17	7		-11						II--
II-	-10								10	0	-10								9		-11							19	9		-11								9	II-
II	-11							13	2	-9							15		-7							16		-5	-16						18		-4			II
II+	-12						18	6	-6	-17							0								6	-5							12		-11					II+
II++	-13						12	-1	-13						11		-14						11								10		-15						x	II++
II.5	-13						6	-7							-1							5	-8						11		-16					17	4	-10		II.5
III--	-14					15	0	-14					15		-14					15		-13					15		-13					16		-13				III--
III-	-15					10	-6						4						14	-2							-7					18	2	-13						III-
III	-16					5	-11						-7						-2	-18					2						7	-9					11			III
III+	-17				17	0	-17				16		-17				16		-17				16		-17				16		-18				16		x			III+
III++	-17				13	-5					8						3						-2					10	-7						-12				18	III++
III.5	-18				9	-10					-1					8	-11				16						7	-12										6	x	III.5
IV--					5	-14					-10					-5					0										9					14	-5			IV--
IV-					1	-19					-18					-17					-17					-16					-15					-14				IV-
IV				17	-3				14					11					8					5					2				19	-1					-5	IV
IV+				15	-7				8					1					-6				8	-13								16	-5				9			IV+
IV++				12	-11				1				13	-10								13	-9								14	-8					-18			IV++
IV.5				9	-14				-6				3				11					-3								14	-9				0					IV.5
V--				6	-18				-12				-7				-1				4	-19			10				16	-8								3		V--
V-				3					-19				-16				-14				-11				-9				-6				-3				-1			V-
V				0									-26		24		-26		23				23				23													V
V+				-3							16				13				10				7				4				1				-2				-6	V+
V++				-6			15				9				3				-3				-9			11	-15							-1						V++
V.5			18	-9			10				1				-8			11	-17							-7			12								-6			V.5
VI--			16	-12			5				-7				-18			-2							3				-9			8							12	VI--
VI-			14	-14			0			14	-14						14	-15						14	-15						14	-15						x	-15	VI-
VI			12	-17			-5			7			19				2							-3			9				-8						16	x		VI
VI+			10				-10			0			11				-9						11	-19			-9						12				-8			VI+
VI++			8				-14			-6			2			10			18				-4						12				-10			2				VI++
VI.5			6				-19			-13			-7			0			6			12	-19		18				-7						5					VI.5
VII--			4							-19			-15			-11			-7			-3			2			6			10			14	-18		18			VII--
VII-			2																-19			-17			-15			-13			-10			-8			-6			VII-
VII			0	-33						-33						-32						-32																		VII
VII+			-3														19			16			14			11			8			6			3			1		VII+
VII.5			-5					19			14			8			3			-3			-8			-13			-19		11						0			VII.5
VIII-			-8					11			3			-5			-13		15						-2					18	-18					2			-7	VIII-
VIII			-11		15			4			-7		19	-18					-3								1			-10					5					VIII
VIII+			-14		11			-3			-17		7					18			4								1					12			-2			VIII+
VIII.5			-16		6			-10					-4					2			-14		8					14			-2			-18						VIII.5
IX-			-19		2			-17					-16					-14					-12					-10					-9					-7		IX-
IX		19			-3		16					14					11					8					5					3					0		x	IX
IX+		17			-7		10					4					-3		14			-10					-17		0		17								-14	IX+
IX.5		16			-11		5					-6					-18		-2							3					-8	7								IX.5
X-		14			-15		-1		13			-17				11			-18				10			-19				9							7			X-
X		12			-19		-7		5		17					-2							-9		3					-16				8					-11	X
X+		11					-13		-2		9		19			-15				7					-17				5		15			-18				3		X+
X.5		9					-18		-9		0		9		18					-9				9					-18		-9				9		18			X.5
XI-		8							-16		-9		-1		6		14							-10				5							-18		-11			XI-
XI		6									-17		-11		-5		1		6		12		18					-17				-5				7				XI
XI+		4													-17		-12		-8		-3		1		6		10		15		19									XI+
XI.5		3																			-19		-16		-13		-10		-7		-4		-1		2		5		x	XI.5
XII-		1													-39		-37				-34		-33																	XII-
XII		0																																						XII
XII+		-1																					34																	XII+
XII.5		-3																					18		15		12		9		7		4		1		-2		-5	XII.5
XIII-		-4													18		14		10		6		2		-3		-7		-11		-15		-19							XIII-
XIII		-6									19		14		8		2		-3		-9		-15									10				-1				XIII
XIII+		-7							19		12		5		-2		-9		-16					17				3				-11								XIII+
XIII.5		-8							13		5		-4		-12					17				1				-16							5		-3			XIII.5
XIV-		-10					16		7		-3		-12							4				-15					11		1				-18			x		XIV-
XIV		-11					12		1		-10					13				-9					14				-8		-19			15				-7		XIV
XIV+		-12					7		-5		-17					3							10		-2					18				-7					x	XIV+
XIV.5		-13			16		3		-10							-7							-4		-18					-1							2		x	XIV.5
XV-		-15			13		-1		-16			12				-17			11				-19			9							8							XV-
XV		-16			10		-6					5					15		-1							-7			19		3		-13							XV
XV+		-17			7		-10					-3					5		-12			12					19		2		-15								x	XV+
XV.5		-18			4		-14					-10					-5					-1					3		-15			8					12		-6	XV.5
XVI-		-19			1		-18					-17					-15					-14					-13					-11					10			XVI-
XVI			19		-2			17					16					14					13					11					10					x		XVI
XVI+			17		-4			13					9					4					0					-4			13		-9					x		XVI+
XVI.5			16		-7			9					1					-6			10		-13						19		-4			11						XVI.5
XVII-			14		-10			4			18		-6					-16			-2								2					-8			7			XVII-
XVII			12		-13			0			12		-13						12		-13						11		-14						11		-14			XVII
XVII+			11		-15			-5			6			17					2								-3			8					-7					XVII+
XVII.5			9		-18			-9			0			10			19		-8						10		-17			-8						11				XVII.5
XVIII-			8					-13			-5			2			10		-18	18					-3						12					-8			-1	XVIII-
XVIII			6					-17			-11			-5			1			7			13		-16	19					-4						8			XVIII
XVIII+			5								-17			-12			-7			-3			2			6			11		-19	15					-10			XVIII+
XVIII.5			3											-19			-16			-13			-10			-7			-3			0			3			x		XVIII.5
XIX-			2																							-19			-18			-16			-15			x		XIX-
XIX			0	33							-33																													XIX
loc./p.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	loc./p.

Appendix G – Detection degree in t.s. 2 of the main partials at each location

The values in each cell are the r.d. values of Appendix B. When the value is typed in bold, the node is at its smallest r.d. from the location. A black background of a location's ID flags type A locations, whereas a dark grey background flags type B locations. The correspondence between the formatting of the values and cells and the detection degree of the partials in t.s. 2 and in t.s. 1 is the following:

- black background – high detection in t.s. 2
- grey background – moderate detection in t.s. 2
- white background, values typed in black – low detection in t.s. 2
- white background, values typed in grey – very low detection in t.s. 2
- white background, values in brackets (typed in grey) – not detected in t.s. 2
- values typed in normal – moderate to high detection in t.s. 1
- values typed in italic – very low to low detection in t.s. 1
- cross – not detected in t.s. 1

loc./p.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	loc./p.
0.5	-3																												19	16	13	10	7	5	(2)	(-1)	(-4)	(-7)	x	0.5
I--	-4																					18	14	10	6	3	-1	-5	-9	-12	(-16)									I--
I-	-5																	16	11	6	2	-3	-8	-12	-17														x	I-
I	-6														16	10	5	-1	-7	-12	-18												15		4		-8		x	I
I+	-6												16	9	3	-4	-10	-17											12		-1		-14							I+
I++	-7										19	11	4	-3	-11	-18									16		1		-14											I++
I.5	-8									17	9	1	-7	-16									10		-7									(19)	(11)		-6	(-14)		I.5
II--	-9								18	9	-1	-10	-19								8		-10								(17)	7		(-11)						II--
II-	-10								10	0	-10								9		-11							19	9		(-11)								(9)	II-
II	(-11)							13	2	-9							15		-7							16		-5	-16						(18)		-4			II
II+	-12						18	6	-6	-17							0								6	-5							12		(-11)					II+
II++	-13						12	-1	-13						11		-14						11		-14						10		(-15)						x	II++
II.5	-13						6	-7							-1							5	-8						11		-16					17	4	(-10)		II.5
III--	(-14)					15	0	-14					15		-14					15		-13					(15)		-13					(16)		(-13)				III--
III-	(-15)					10	-6						4						14	-2							-7					18	2	(-13)						III-
III	(-16)					5	-11						-7						-2	-18					2						7	-9					11			III
III+	(-17)				17	0	-17				16		-17				16		-17				16		-17				16		(-18)				(16)		x			III+
III++	(-17)				13	-5					8						3						-2					10	-7						(-12)				(18)	III++
III.5	(-18)				9	-10					-1					8	-11				16						7	-12										(6)	x	III.5
IV--					5	-14					-10					-5					0					5	-15				9					(14)	-5			IV--
IV-					1	-19					-18					-17					-17					-16					-15					(-14)				IV-
IV				17	-3				14					11					8					5					2				19	-1					(-5)	IV
IV+				15	-7				8					1					-6				8	-13								16	-5				9			IV+
IV++				12	-11				1				13	-10								13	-9								14	-8					-18			IV++
IV.5				9	-14				-6				3				11					-3								14	-9				0					IV.5
V--				6	-18				-12				-7				-1				4	-19			10				16	-8								(3)		V--
V-				3					-19				-16				-14				-11				-9				-6				-3				-1			V-
V				0									-26		24		-26		23				23				23													V
V+				-3							16				13				10				7				4				1				(-2)				(-6)	V+
V++				-6			15				9				3				-3				-9			11	(-15)							-1						V++
V.5			18	-9			10				1				-8			11	-17							-7			12								(-6)			V.5
VI--			16	-12			5				-7				-18			-2							3				-9			8							(12)	VI--
VI-			14	-14			0			14	-14						14	-15						14	-15						(14)	-15						x	(-15)	VI-
VI			12	-17			-5			7			19				2							-3			9				-8						(16)	x		VI
VI+			10				-10			0			11				-9						11	-19			-9						12				(-8)			VI+
VI++			8				-14			-6			2			10			18				-4						12				(-10)			(2)				VI++
VI.5			6				-19			-13			-7			0			6			12	-19		18				-7						5					VI.5
VII--			4							-19			-15			-11			-7			-3			2			6			(10)			(14)	(-18)		(18)			VII--
VII-			2																-19			-17			-15			-13			-10			-8			(-6)			VII-
VII			0	-33						-33						-32						-32																		VII
VII+			-3														19			16			14			11			8			6			(3)			(1)		VII+
VII.5			-5					19			14			8			3			-3			-8			-13			-19		11						0			VII.5
VIII-			-8					11			3			-5			-13		15						-2					18	(-18)					(2)			(-7)	VIII-
VIII			-11		15			4			-7		19	-18					-3								1			-10					5					VIII
VIII+			-14		11			-3			-17		7					18			4								1					(12)			-2			VIII+
VIII.5			-16		6			-10					-4					2			-14		8					14			-2			(-18)						VIII.5
IX-			-19		2			-17					-16					-14					-12					-10					(-9)					(-7)		IX-
IX		19			-3		16					14					11					8					5					3					(0)		x	IX
IX+		17			-7		10					4					-3		14			-10					-17		0		(17)								(-14)	IX+
IX.5		16			-11		5					-6					-18		-2							3					-8		7							IX.5
X-		14			-15		-1		13			-17				11			-18				10			-19				9							7			X-
X		12			-19		-7		5		17					-2							-9		3					-16				(8)					(-11)	X
X+		11					-13		-2		9		19			-15				7					-17				5		(15)			(-19)				(3)		X+
X.5		9					-18		-9		0		9		18					-9				9					-18		-9				9		(18)			X.5
XI-		8							-16		-9		-1		6		14							-10				5							-18		-11			XI-
XI		6									-17		-11		-5		1		6		12		18					-17				-5				(7)				XI
XI+		4													-17		-12		-8		-3		1		6		10		15		(19)									XI+
XI.5		3																			-19		-16		-13		-10		-7		-4		(-1)		(2)		(5)		x	XI.5
XII-		1													-39		-37				-34		-33																	XII-
XII		0																																						XII
XII+		-1																					(34)																	XII+
XII.5		-3																					18		15		(12)		(9)		7		4		(1)		(-2)		(-5)	XII.5
XIII-		-4													18		14		10		6		2		-3		-7		-11		-15		-19							XIII-
XIII		-6									19		14		8		2		-3		-9		-15									10				(-1)				XIII
XIII+		-7							19		12		5		-2		-9		-16					17				3				-11								XIII+
XIII.5		-8							13		5		-4		-12					17				1				-16							5		-3			XIII.5
XIV-		-10					16		7		-3		-12							4				-15					11		(1)				-18			x		XIV-
XIV		-11					12		1		-10					13				-9					14				-8		-19			(15)				(-7)		XIV
XIV+		-12					7		-5		-17					3							10		-2					(18)				-7					x	XIV+
XIV.5		-13			16		3		-10							-7							-4		-18					-1							2		x	XIV.5
XV-		-15			13		-1		-16			12				-17			11				-19			9							(8)							XV-
XV		-16			10		-6					5					15		-1							-7			(19)		3		-13							XV
XV+		-17			7		-10					-3					5		-12			12					(19)		2		-15								x	XV+
XV.5		-18			4		-14					-10					-5					-1					3		-15			(8)					(12)		-6	XV.5
XVI-		-19			1		-18					-17					-15					-14					-13					(-11)					(10)			XVI-
XVI			19		-2			17					16					14					13					11					(10)					x		XVI
XVI+			17		-4			13					9					4					0					-4			(13)		-9					x		XVI+
XVI.5			16		-7			9					1					-6			10		-13						(19)		(-4)			(11)						XVI.5
XVII-			14		-10			4			18		-6					-16			-2								2					(-8)			7			XVII-
XVII			12		-13			0			12		-13						12		-13						11		-14						(11)		-14			XVII
XVII+			11		-15			-5			6			17					2								-3			(8)					-7					XVII+
XVII.5			9		-18			-9			0			10			19		-8						10		-17			-8						(11)				XVII.5
XVIII-			8					-13			-5			2			10		-18	18					-3						(12)					(-8)			(-1)	XVIII-
XVIII			6					-17			-11			-5			1			7			13		-16	19					-4						(8)			XVIII
XVIII+			5								-17			-12			-7			-3			2			6			11		-19	15					(-10)			XVIII+
XVIII.5			3											-19			-16			-13			-10			-7			-3			(0)			(3)			x		XVIII.5
XIX-			2																							-19			(-18)			(-16)			(-15)			x		XIX-
XIX			0	33							-33																													XIX
loc./p.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	loc./p.

Appendix H – Relative loudness categories of the reliable main partials at each location in t.s. 1

The values in each cell are the r.d. values of Appendix B. When the value is typed in bold, the node is at its smallest r.d. from the location. A black background of a location's ID flags type A locations, whereas a dark grey background flags type B locations. The correspondence between the formatting of the values and cells and the relative loudness of the partials and their reliability is the following:

- black background – loud
- grey background – moderately loud
- white background, values typed in black – soft
- white background, values typed in grey – very soft
- white background, values in brackets (typed in grey) – not perceivable
- values in square brackets – totally masked
- values typed in normal – moderate to high detection
- values typed in italic – very low to low detection
- asterisk – l.m.p.

loc./p.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	loc./p.
0.5	-3*																											19	16	13	10	7	5				-7		0.5
I--	-4*																				18	14	10	6	3	-1	-5	-9	-12									I--
I-	-5																16	11	6	2*	-3	-8	-12	-17														I-
I	-6													16	10	5	-1*	-7	-12	-18											15		4		-8			I
I+	-6											16	9	3	-4*	-10	-17										12		-1		-14						I+
I++	-7									19	11	4	-3*	-11	-18								16		1		-14										I++
I.5	-8								17	9	1*	-7	-16								10		-7								19	11		-6			I.5
II--	-9							18	9	-1*	-10	-19							8		-10							17	7		-11					II--
II-	-10							10	0*	-10							9		-11						19	9		-11							9	II-
II	-11						13	2*	-9						15		-7						16		-5	-16					18		-4			II
II+	-12					18	6	-6*	-17						0							6	-5						12		-11				II+
II++	-13					12	-1*	-13					11		-14					11		-14					10		-15						II++
II.5	-13					6*	-7						-1						5	-8					11		-16				17	4			II.5
III--	-14				15	0*	-14				15		-14				15		-13				15		-13				16		-13				III--
III-	-15				10	-6*					4					14	-2						-7				18	2	-13					III-
III	-16				5*	-11					-7					-2	-18				2					7	-9				11			III
III+	-17			17	0*	-17			16		-17			16		-17			16		-17			16		-18			16				III+
III++	-17			13	-5*				8					3					-2				10	-7					-12			18	III++
III.5	-18			9*	-10				-1				8	-11			16					7	-12									6		III.5
IV--					5*	-14				-10				-5				0				5	-15			9					-5			IV--
IV-					1*	-19				[-18]				-17				-17				-16				-15				-14				IV-
IV				17	-3*			14				11				8				5				2			19	-1				-5	IV
IV+				15	-7*			8				1				-6			8	-13							16	-5			9			IV+
IV++				12	-11			1*			13	-10							13	-9							14	-8				-18			IV++
IV.5				9	-14			-6			3*			11				-3							14	-9			0				IV.5
V--				6*	-18			-12			-7			-1			4	-19		10			16	-8							3		V--
V-				3*				[-19]			-16			-14			-11			-9			-6			-3			-1			V-
V				0*								-26		24		-26		23			23			23												V
V+				-3*						16			13			10			7			4			1			-2			-6	V+
V++				-6*		15			9			3			-3			-9		11	-15						-1						V++
V.5			18	-9		10			1*			-8		11	-17						-7		12							-6			V.5
VI--			16	-12		5*			-7			-18		-2						3			-9		8						12	VI--
VI-			14	-14		0*		14	-14					14	-15					14	-15					14	-15						-15	VI-
VI			12	-17		-5*		7		19			2						-3		9			-8									VI
VI+			10			-10		0*		11			-9					11	-19		-9					12			-8			VI+
VI++			8			-14		-6		2*		10		18			-4					12			-10		2				VI++
VI.5			6*			-19		-13		-7		0		6		12	-19		18			-7					5					VI.5
VII--			4*						-19		-15		-11		-7		-3		2		6		10		14	-18		18			VII--
VII-			2*															-19		-17		-15		-13		-10		-8		-6			VII-
VII			0*	[-33]					-33					-32					-32																	VII
VII+			-3*													19		16		14		11		8		6		3		1		VII+
VII.5			-5*				19		14		8		3		-3		-8		-13		-19		11					0			VII.5
VIII-			-8*				11		3		-5		-13		15					-2				18	-18				2		-7	VIII-
VIII			-11		15		4*		-7		19	-18				-3							1		-10				5					VIII
VIII+			-14		11		-3*		-17		7				18		4							1				12		-2			VIII+
VIII.5			-16		6*		-10				-4				2		-14		8				14		-2		-18						VIII.5
IX-			-19		2*		-17				-16				-14				-12				-10				-9							IX-
IX		19		-3*		16				14				11				8				5				3				0			IX
IX+		17		-7*		10				4				-3		14		-10				-17		0									-14	IX+
IX.5		16		-11		5*				-6				-18		-2						3				-8		7							IX.5
X-		14		-15		-1*		13		-17			11		-18			10		-19			9						7			X-
X		12		-19		-7*		5		17				-2						-9		3				-16			8				-11	X
X+		11				-13		-2*		9		19		-15			7				-17			5				-19						X+
X.5		9				-18		-9		0*		9		18				-9			9				-18		-9			9		18			X.5
XI-		8						-16		-9		-1*		6		14						-10			5						-18		-11			XI-
XI		6*								-17		-11		-5		1		6		12		18				-17			-5			7				XI
XI+		4*												-17		-12		-8		-3		1		6		10		15		19									XI+
XI.5		3*																		-19		-16		-13		-10		-7		-4		-1		2		5			XI.5
XII-		1*												[-39]		[-37]			-34		-33																XII-
XII		0*																																					XII
XII+		-1*																				34																XII+
XII.5		-3*																				18		15		12		9		7		4		1		-2			XII.5
XIII-		-4*												18		14		10		6		2		-3		-7		-11		-15		-19							XIII-
XIII		-6*								19		14		8		2		-3		-9		-15								10			-1				XIII
XIII+		-7*						19		12		5		-2		-9		-16				17			3			-11								XIII+
XIII.5		-8						13		5		-4*		-12				17			1			-16						5		-3			XIII.5
XIV-		-10				16		7		-3*		-12						4			-15				11		1			-18					XIV-
XIV		-11				12		1*		-10				13			-9				14			-8		-19		15			-7		XIV
XIV+		-12				7		-5		-17				3						10		-2				18			-7						XIV+
XIV.5		-13		16		3*		-10						-7						-4		-18				-1						2			XIV.5
XV-		-15		13		-1*		-16		12			-17		11			-19		9													XV-
XV		-16		10		-6*				5				15		-1						-7		19		3		-13							XV
XV+		-17		7*		-10				-3				5		-12		12				19		2		-15									XV+
XV.5		-18		4*		-14				-10				-5				-1				3		-15		8				12		-6	XV.5
XVI-		-19		1*		[-18]				-17				-15				-14				-13				-11				10			XVI-
XVI			19		-2*		17				16				14				13				11				10							XVI
XVI+			17		-4*		13				9				4				0				-4		(13)		-9							XVI+
XVI.5			16		-7*		9				1				-6		10		-13					19		-4		11						XVI.5
XVII-			14		-10		4*		18		-6				-16		-2							2				-8		7			XVII-
XVII			12		-13		0*		12		-13					12		-13					11		-14							-14			XVII
XVII+			11		-15		-5*		6		17				2							-3		8				-7					XVII+
XVII.5			9		-18		-9		0*		10		19		-8					10		-17		-8					11				XVII.5
XVIII-			8				-13		-5*		2		10		-18	18				-3					12				-8		-1	XVIII-
XVIII			6*				-17		-11		-5		1		7		13		-16	19				-4									XVIII
XVIII+			5*							-17		-12		-7		-3		2		6		11		-19	15				-10			XVIII+
XVIII.5			3*										-19		-16		-13		-10		-7		-3		0		3					XVIII.5
XIX-			2*																						-19		-18		-16		-15					XIX-
XIX			0*	33						-33																												XIX
loc./p.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	loc./p.

Appendix I – Relative loudness categories of the reliable main partials at each location in t.s. 2

The values in each cell are the r.d. values of Appendix B. When the value is typed in bold, the node is at its smallest r.d. from the location. A black background of a location's ID flags type A locations, whereas a dark grey background flags type B locations. The correspondence between the formatting of the values and cells and the relative loudness of the partials and their reliability is the following:

- black background – loud
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- values in square brackets – totally masked
- values typed in normal – moderate to high reliability
- values typed in italic – very low to low reliability
- asterisk – l.m.p.

loc./p.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	loc./p.
0.5	-3*																												19	16	13	10	7	5						0.5
I--	-4*																					18	14	10	6	3	-1	-5	-9	-12										I--
I-	-5																	[16]	[11]	6	2*	-3	-8	-12	-17															I-
I	-6														[16]	10	5	-1*	-7	-12	-18												15		4		-8			I
I+	-6												[16]	9	3	-4*	[-10]	[-17]											12		-1									I+
I++	-7										[19]	11	4	-3*	-11	[-18]									16		1		-14											I++
I.5	-8									17	9	1*	-7	[-16]									10		-7												-6			I.5
II--	-9								18	9	-1*	-10	[-19]								8		-10									7								II--
II-	-10								10	0*	-10								9		-11								9											II-
II								13	2*	-9							15		-7							(16)		-5	-16								(-4)			II
II+	-12						18	6	-6*	-17							0								6	-5							12							II+
II++	(-13)						12	-1*	-13						11		-14						11		(-14)						(10)									II++
II.5	-13						6*	-7							-1							5	-8						11											II.5
III--						15	0*	[-14]					15		-14					15		-13							(-13)											III--
III-						10	-6*						4						14	-2							-7					18	2							III-
III						5*	[-11]						-7						-2	(-18)					2						(7)	(-9)					(11)			III
III+					[17]	0*	(-17)				(16)		(-17)				(16)		(-17)				(16)		(-17)				(16)		(-18)				(16)		(-18)			III+
III++					13	-5*					8						3						-2					(10)	(-7)											III++
III.5					9*	-10					-1					8	-11				16						7	(-12)												III.5
IV--					5*	[-14]					-10					-5					0					5	(-15)										-5			IV--
IV-					1*	(-19)					(-18)					(-17)					(-17)					(-16)					(-15)									IV-
IV				[17]	-3*				[14]					11					8					5					(2)											IV
IV+				15	-7*				8					1					-6				8	-13								16	-5				(9)			IV+
IV++				12	-11				1*				13	-10								13	-9								14	-8					(-18)			IV++
IV.5				9	-14				-6				3*				11					-3								14					0					IV.5
V--				6*	[-18]				[-12]				-7				-1				4	(-19)			10				(16)	-8										V--
V-				3*					[-19]				(-16)				(-14)				-11				-9				-6				-3				-1			V-
V				0*									(-26)		(24)		(-26)		(23)				(23)																	V
V+				-3*							16				13				10				7				4				1									V+
V++				-6*			15				9				3				-3				-9			11								-1						V++
V.5			18	-9			10				1*				-8			11	-17							-7			12											V.5
VI--			16	-12			5*				-7				-18			-2							3				-9			8								VI--
VI-			14	-14			0*			14	[-14]						14	-15						14	-15							-15								VI-
VI			12	-17			-5*			7			19				2							-3			9													VI
VI+			10				-10			0*			11				-9						11	-19			-9						12							VI+
VI++			8				-14			-6			2*			10			18				-4						12											VI++
VI.5			6*				[-19]			-13			-7			0			6			12	-19		18				-7						5					VI.5
VII--			4*							-19			-15			-11			-7			-3			2															VII--
VII-			2*																-19			(-17)			-15			-13			-10			(-8)						VII-
VII			0*	(-33)						(-33)						(-32)						(-32)																		VII
VII+			-3*														(19)			(16)			(14)						(8)											VII+
VII.5			-5*					[19]			14			8			3			-3			-8						-19		11						0			VII.5
VIII-			-8*					11			3			-5			[-13]		15						-2					18										VIII-
VIII			-11		15			4*			-7		19	-18					-3								1			-10										VIII
VIII+			-14		11			-3*			-17		7					18			4								1								-2			VIII+
VIII.5			-16		6*			-10					-4					2			-14		8								-2									VIII.5
IX-			(-19)		2*			(-17)					-16					(-14)					(-12)					(-10)												IX-
IX		19			-3*		[16]					(14)					11					(8)					(5)					(3)								IX
IX+		17			-7*		10					4					-3		(14)			-10					-17		(0)											IX+
IX.5		16			-11		5*					-6					-18		-2							3					-8		7							IX.5
X-		14			-15		-1*		13			-17				11			(-18)				10			-19											7			X-
X		12			-19		-7*		5		17					-2							-9		3					-16										X
X+		11					-13		-2*		9		[19]			-15				7					-17				5											X+
X.5		9					-18		-9		0*		9		[18]					-9				9							-9				9					X.5
XI-		8							-16		-9		-1*		6		[14]							-10				5												XI-
XI		6*									[-17]		-11		-5		1		[6]		12		18					-17												XI
XI+		4*													[-17]		-12		-8		-3		1		6		10		15											XI+
XI.5		3*																			-19		-16		-13		-10		-7											XI.5
XII-		1*													(-39)		(-37)				(-34)		(-33)																	XII-
XII		0*																																						XII
XII+		-1*																																						XII+
XII.5		-3*																					(18)		(15)															XII.5
XIII-		-4*													[18]		[14]		[10]		6		2		-3		-7		-11		-15		-19							XIII-
XIII		-6*									[19]		[14]		8		2		[-3]		-9		-15																	XIII
XIII+		-7*							[19]		[12]		5		-2		-9		[-16]									3												XIII+
XIII.5		-8							[13]		5		-4*		-12					[17]				1				-16									-3			XIII.5
XIV-		-10					[16]		7		-3*		-12							4				-15					11											XIV-
XIV		-11					12		1*		-10					13				-9					14				-8		-19									XIV
XIV+		-12					7		-5*		-17					3							10		-2									-7						XIV+
XIV.5		-13			16		3*		-10							-7							-4		-18					-1							2			XIV.5
XV-		-15			13		-1*		[-16]			12				-17		11					-19			(9)														XV-
XV		-16			10		-6*					5					(15)		-1							-7							-13							XV
XV+		-17			7*		-10					-3					5		-12			(12)							2											XV+
XV.5		(-18)			4*		[-14]					-10					-5					-1					(3)		-15											XV.5
XVI-					1*		(-18)					(-17)					(-15)					(-14)					(-13)													XVI-
XVI			19		-2*			(17)					(16)					(14)					(13)																	XVI
XVI+			17		-4*			[13]					9					4					0					(-4)					(-9)							XVI+
XVI.5			16		-7*			9					1					-6			10		-13																	XVI.5
XVII-			14		-10			4*			18		-6					-16			-2								2								7			XVII-
XVII			12		-13			0*			12		-13						12		-13						11										-14			XVII
XVII+			11		-15			-5*			6			17					2								-3													XVII+
XVII.5			9		-18			-9			0*			10			19		-8						10		-17			-8										XVII.5
XVIII-			8					-13			-5*			2			10		-18	18					-3															XVIII-
XVIII			6*					[-17]			-11			-5			1			7			13		-16	19														XVIII
XVIII+			5*								[-17]			-12			-7			-3			2			6														XVIII+
XVIII.5			3*											-19			-16			-13			-10			-7			-3											XVIII.5
XIX-			2*																							(-19)														XIX-
XIX			0*	(35)							(-27)																													XIX
loc./p.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	loc./p.

Publications by the author in the context of this thesis*

Torres, R., & Ferreira-Lopes P. (2012). Multiphonics as a compositional element in writing for amplified guitar (1). In *Korean Electro-Acoustic Music Society's 2012 Annual Conference: Proceedings*, pp. 73-83.

Torres, R., & Ferreira-Lopes P. (2012). Multiphonics as a compositional element in writing for amplified guitar (1) [rev.]. *Emille*, 10, 55-65. Retrievable from http://keams.org/emille/emille/emille_10/1-6_torres&ferreira-lopes.pdf

Torres, R., & Ferreira-Lopes P. (2012). Multiphonics as a compositional element in writing for amplified guitar (2). *Journal of Science and Technology of the Arts*, 4(1), 61-69. doi: 10.7559/citarj.v4i1.67 [A corrigenda sheet is retrievable from www.ritatorres.eu/citarj-corrigenda.pdf]

Torres, R., & Ferreira-Lopes P. (2013). Guitar multiphonics: Notations for a formalized approach. In F. Scarduelli, & F. Aguera (Eds.), *VII Simpósio Acadêmico de Violão da EMBAP: Anais do evento,* pp. 263-281. Curitiba: EMBAP. Retrievable from http://www.embap.pr.gov.br/arquivos/File/simposio/violao2014/Anais_do_VII_Simposio_EMBAP.pdf

Torres, R., & Ferreira-Lopes P. (2014). Towards overcoming the guitar's color research gap**.** *Revista Vórtex*, *2*(1), 16-36. Retrievable from http://www.revistavortex.com/torres_v2_n1.pdf

Torres, R., & Ferreira-Lopes P. (2014). Guitar multiphonics: Influence of amplification. In T. Klouche, & E. R. Miranda (Eds.), *Proceedings of the 9th Conference on Interdisciplinary Musicology*, pp. 276-279. Berlin: Staatliches Institut für Musikforschung.

Torres, R., Ferreira-Lopes, P. (in press). The sound world of guitar multiphonics. In M. Doğantan-Dack, & J. Dack (Eds.), *Music and Sonic Art: Theories and Practices*. Cambridge: Cambridge Scholars Publishing.

Musical compositions by the author in the context of this thesis

The fireflies, twinkling among leaves, make the stars wonder for guitar and live electronics (GEMA work no.: 16077093)

Si amanece nos vamos for guitar (GEMA work no.: 15928960; premiered by Jürgen Ruck on May 9, 2015 at the *Festival Terras sem Sombra* in Santiago do Cacém, Portugal)

* Citations by other authors of one or more of these publications can be found in Josel and Tsao (2014, p. 118), Kubilay, I. A., Vesilkkala, J. T., Pàmies-Vilà, M., Kuusi, T., and Välimäki, V. (2015, p. 2), Schneider (2015, p. 113, endnote 26) and Vishnick (2014, p. 239).

UNIVERSIDADE CATÓLICA PORTUGUESA

A NEW CHEMISTRY OF SOUND:
THE TECHNIQUE OF MULTIPHONICS AS A COMPOSITIONAL ELEMENT FOR GUITAR AND AMPLIFIED GUITAR

Thesis submitted to the Portuguese Catholic University to obtain the degree of
Doctor of Philosophy in Science and Technology of the Arts
Area of expertise: Computer Music

By Rita Luzes Torres

Supervised by Prof. Dr. Paulo Ferreira Lopes and Prof. Dr. Thomas A. Troge

Volume 2

ESCOLA DAS ARTES

September 2015

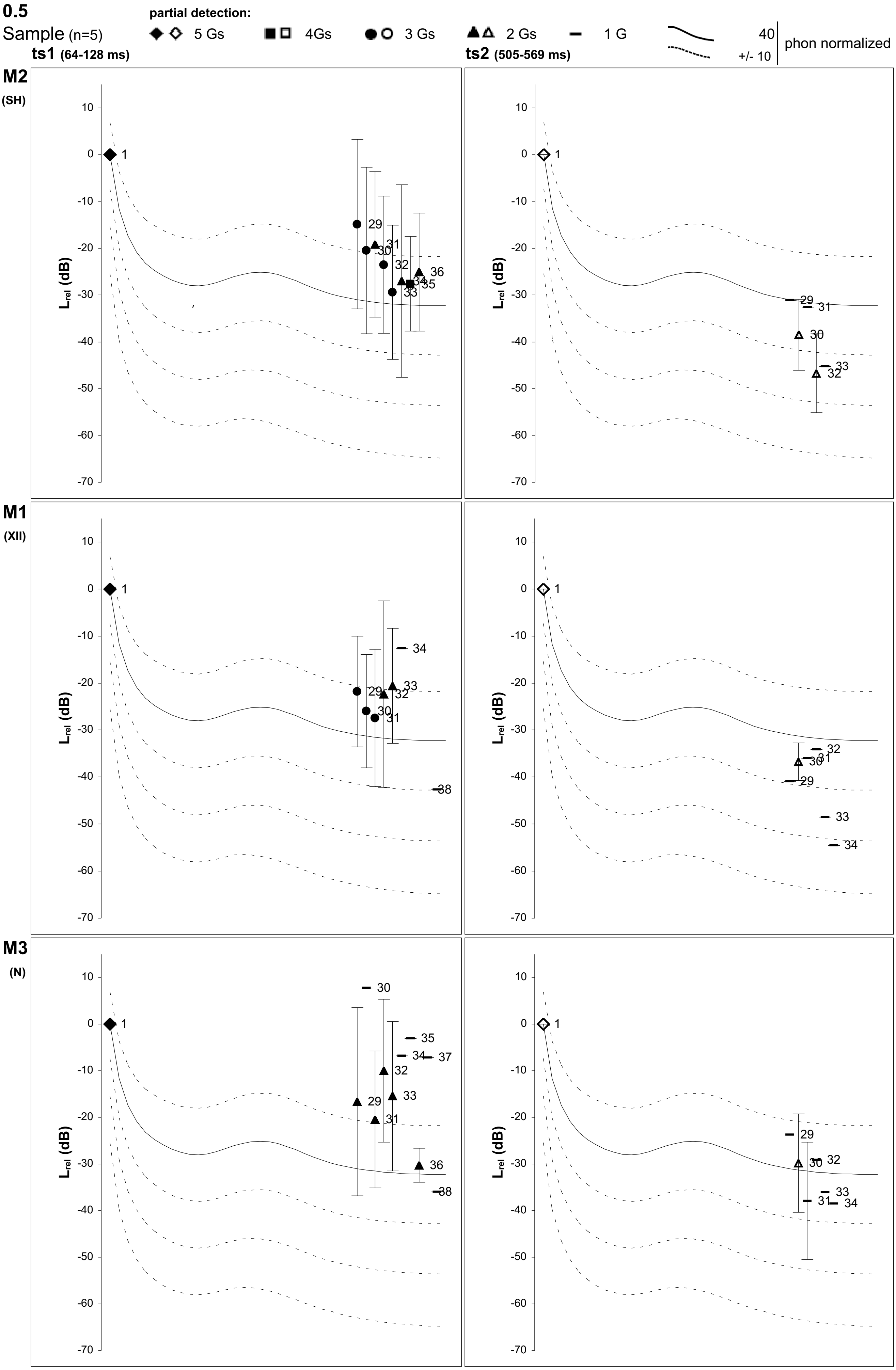
The first part of this volume contains the treated data of the experiment. This data was arrived at through the method described in section 3.1.4 of Volume 1; its evaluation gave rise to the results presented in section 4.1. The data is organized by location ID from v.f. 0.5 to fret XIX. For each location there are four pages: the first contains the data of the sample at each of the three microphones, and each of the other pages contain the data of each guitarist (G) at each microphone (M). When “2Ts” or “1T” appears near a graph of an individual element, this means respectively that all means values were calculated with only two takes or the values stem from only one take (in case of guitarist 5), because either a whole take or a time segment of a take was discarded. This volume's second part contains the scores of the two musical compositions in which the results of the research and assumptions based thereon were implemented.

Contents

Part 1 – Treated Data

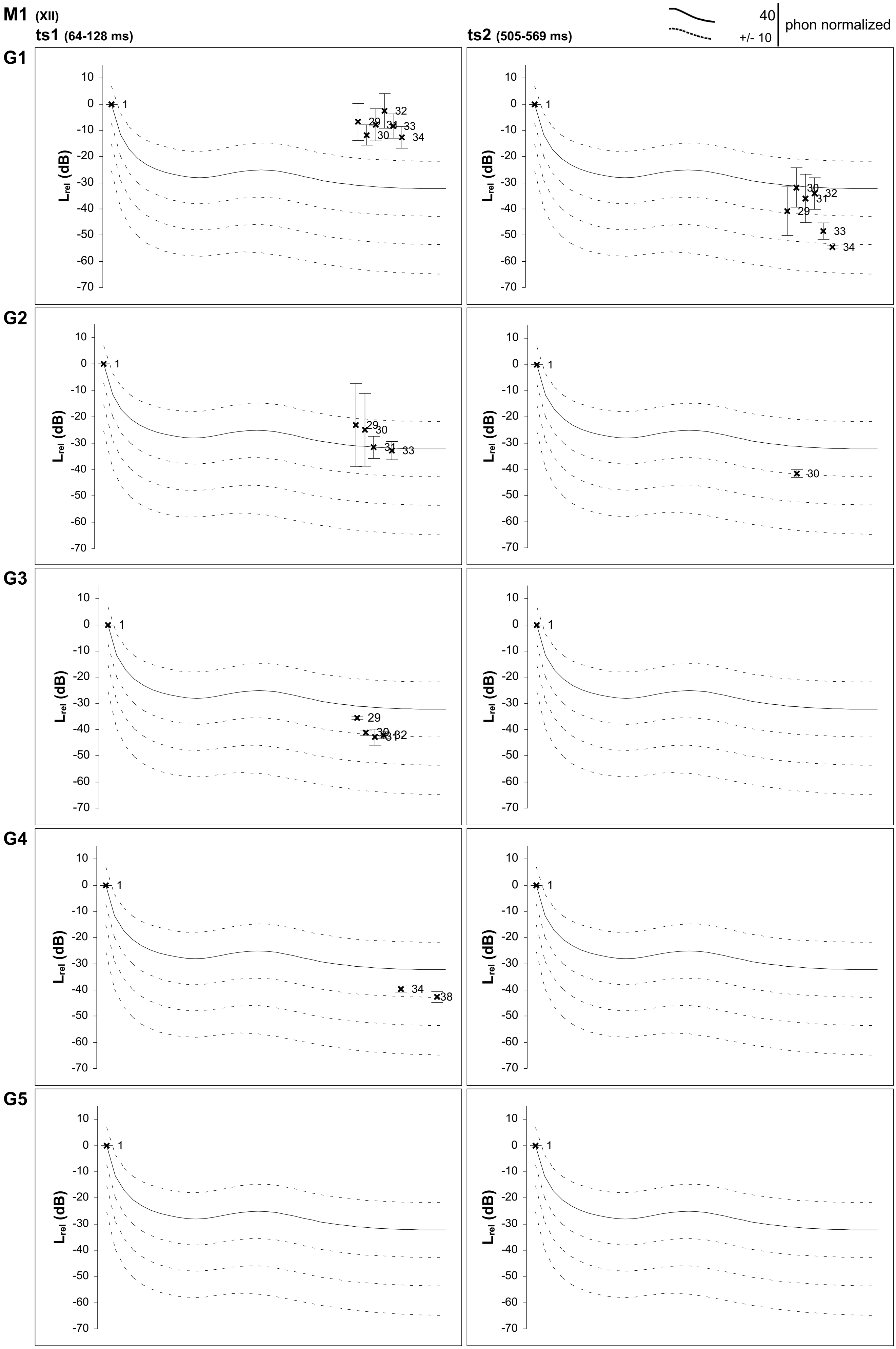
Part 2 – Scores

Part 1



0.5
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_rel (dB)

0.5
M1 (XII)


40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
G1
G2
G3
G4
G5
L_rel (dB)
10
0
-10
-20
-30
-40
-50
-60
-70
1
29
30
31
32
33
34
38

0.5

M2 **(Sound hole)**

ts1 **(64-128 ms)** **ts2** **(505-569 ms)**

40 / +/- 10 phon normalized

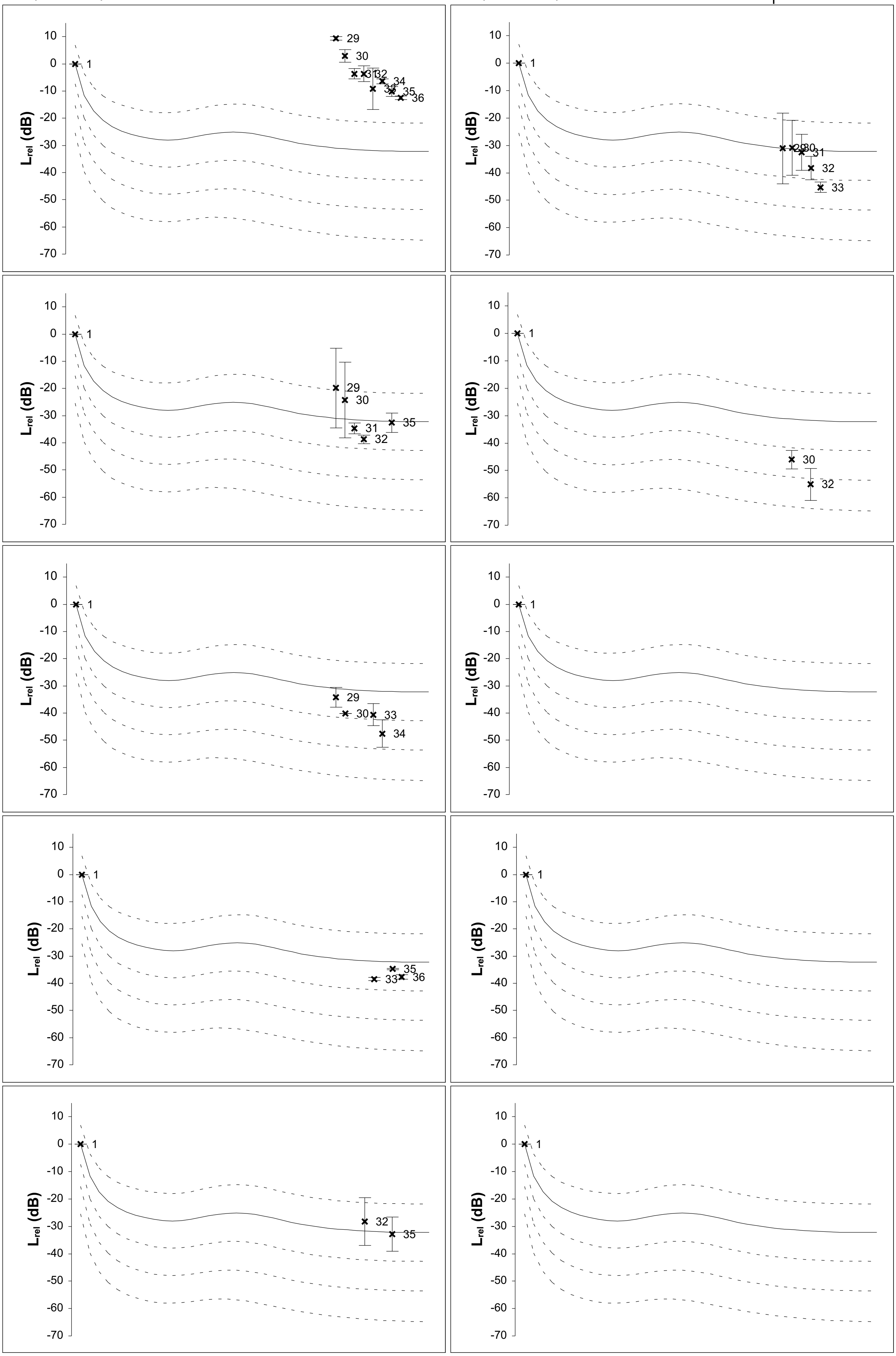
G1 (2Ts)

G2

G3

G4

G5



0.5

M3 (Neck)

40 | phon normalized
+/- 10

ts1 (64-128 ms) **ts2** (505-569 ms)

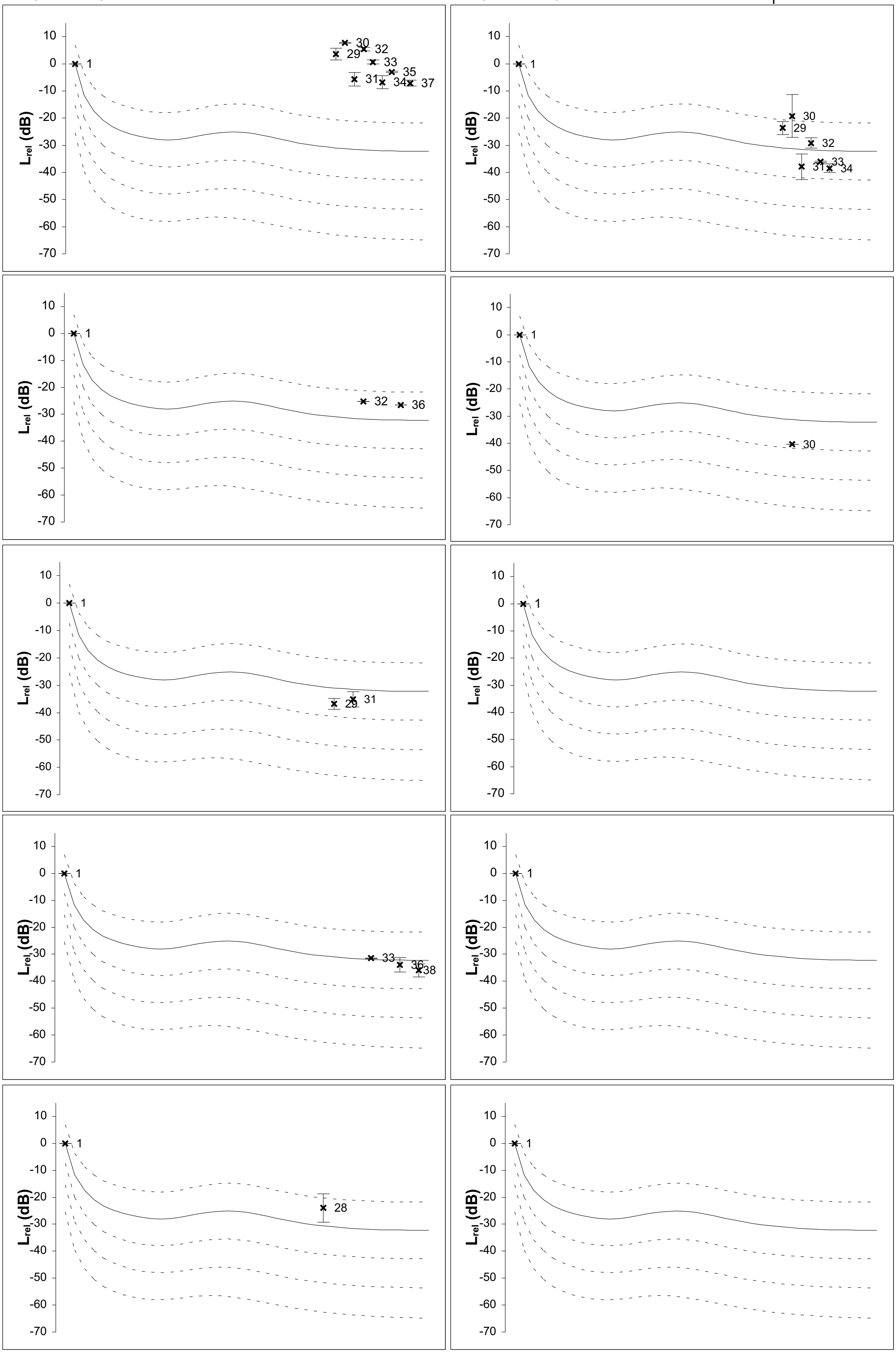
G1 (2Ts)

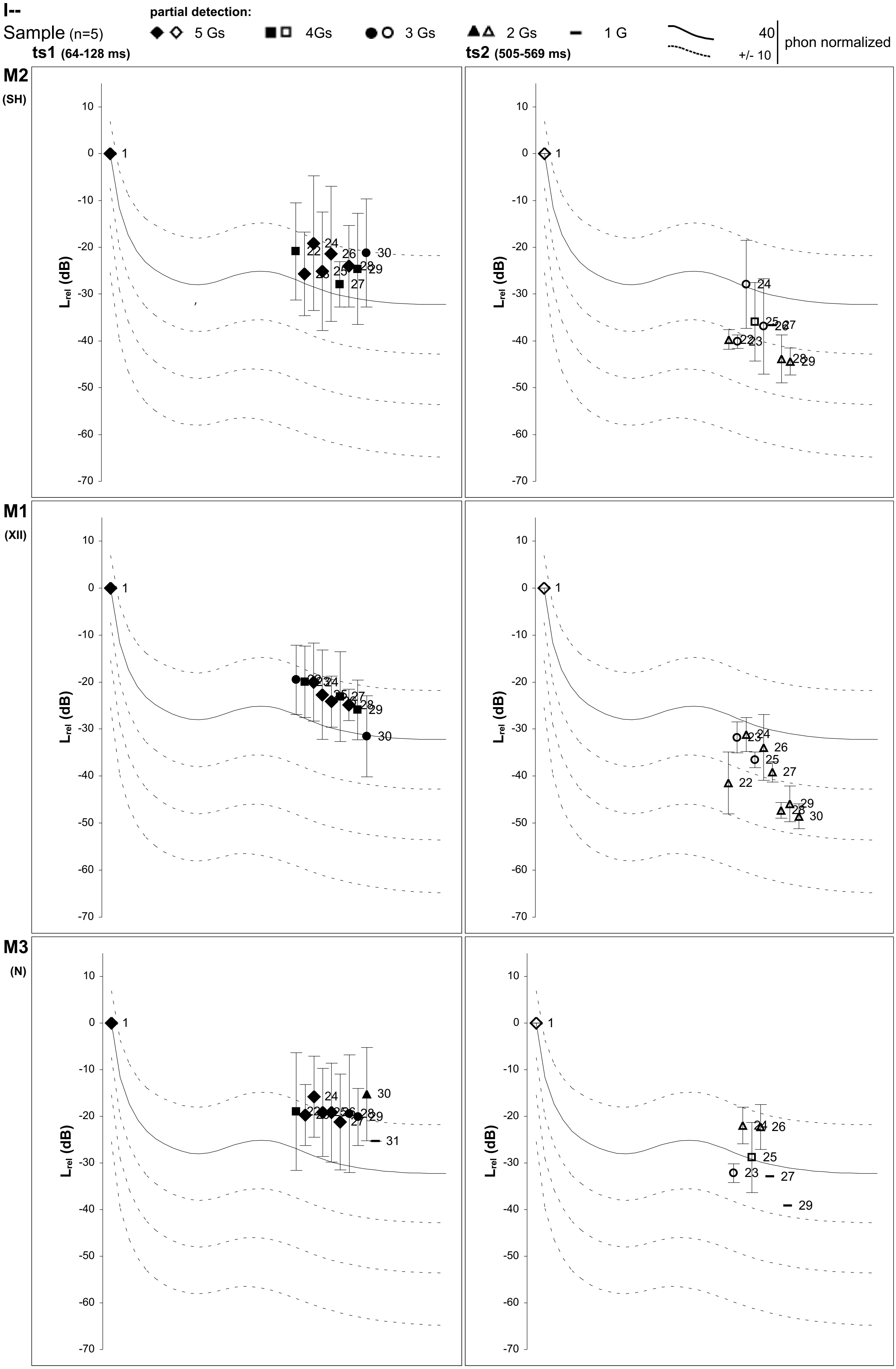
G2

G3

G4

G5




I--
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_rel (dB)
10
0
-10
-20
-30
-40
-50
-60
-70

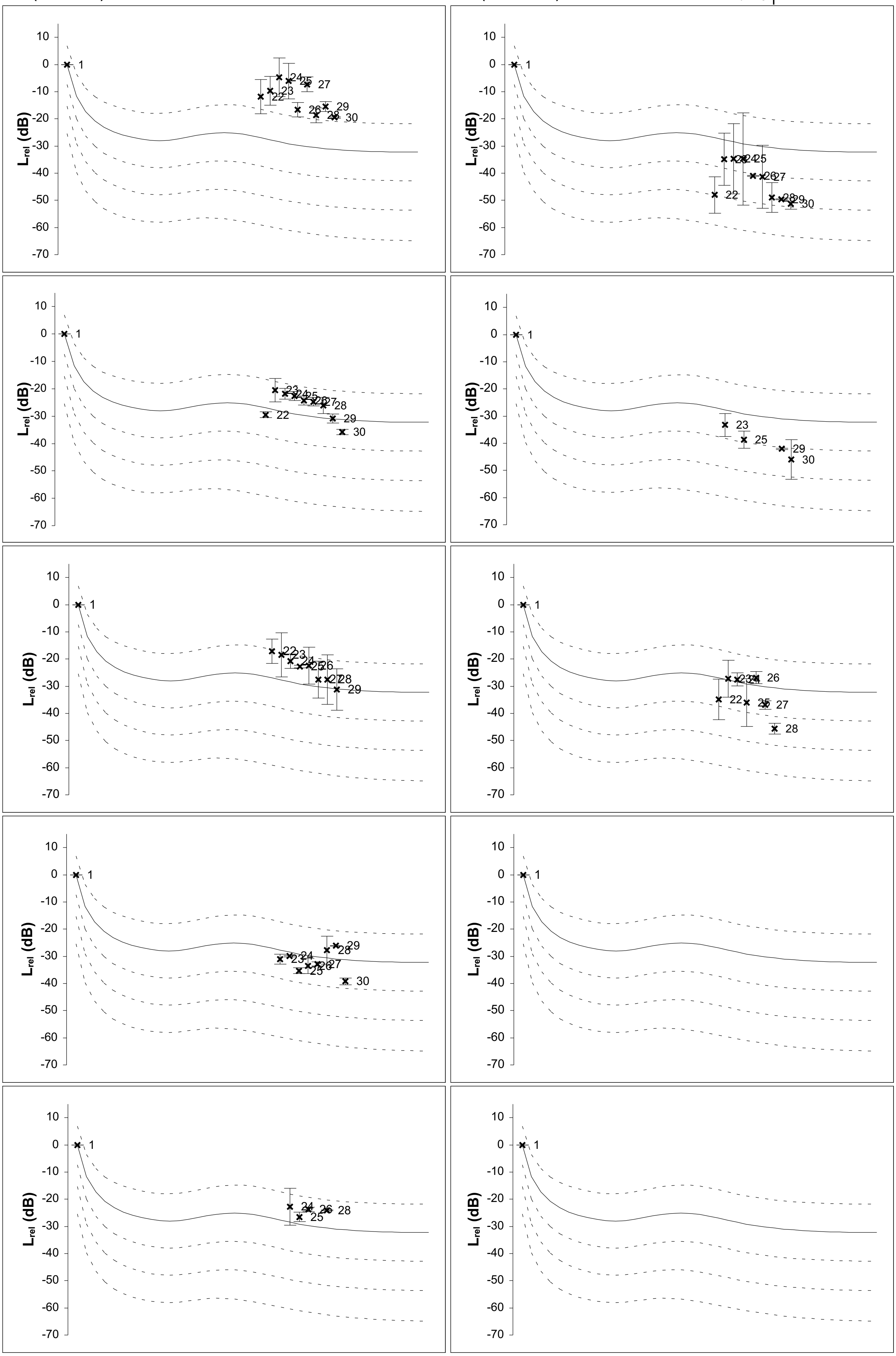
I--

M1 (XII)

40 — phon normalized
+/- 10

ts1 (64-128 ms) **ts2** (505-569 ms)

G1
G2
G3
G4
G5



I--

M2 (Sound hole)

ts1 (64-128 ms) **ts2** (505-569 ms)

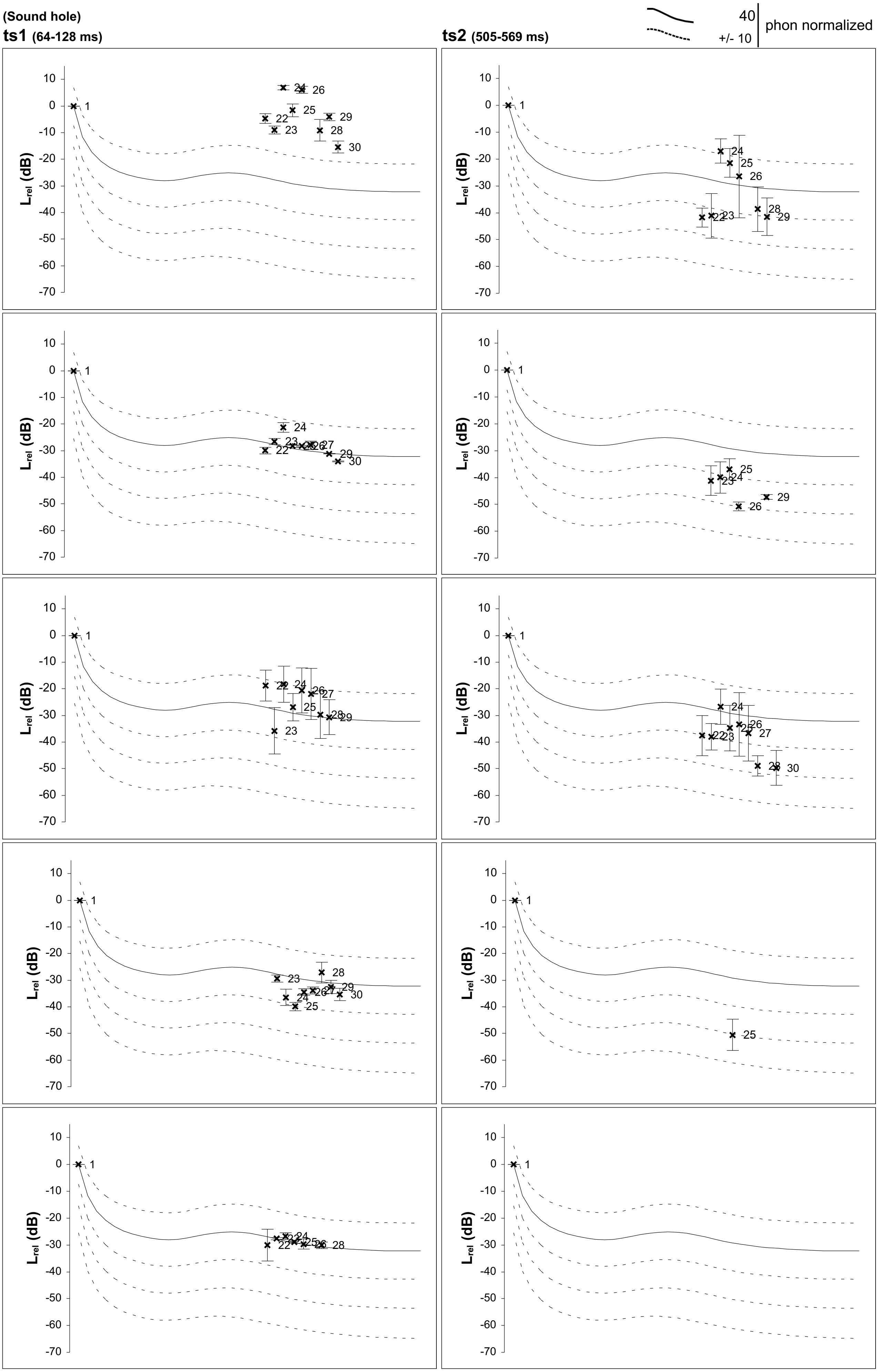
G1 (2Ts)

G2

G3

G4

G5



I--

M3 (Neck)

ts1 (64-128 ms) ts2 (505-569 ms)

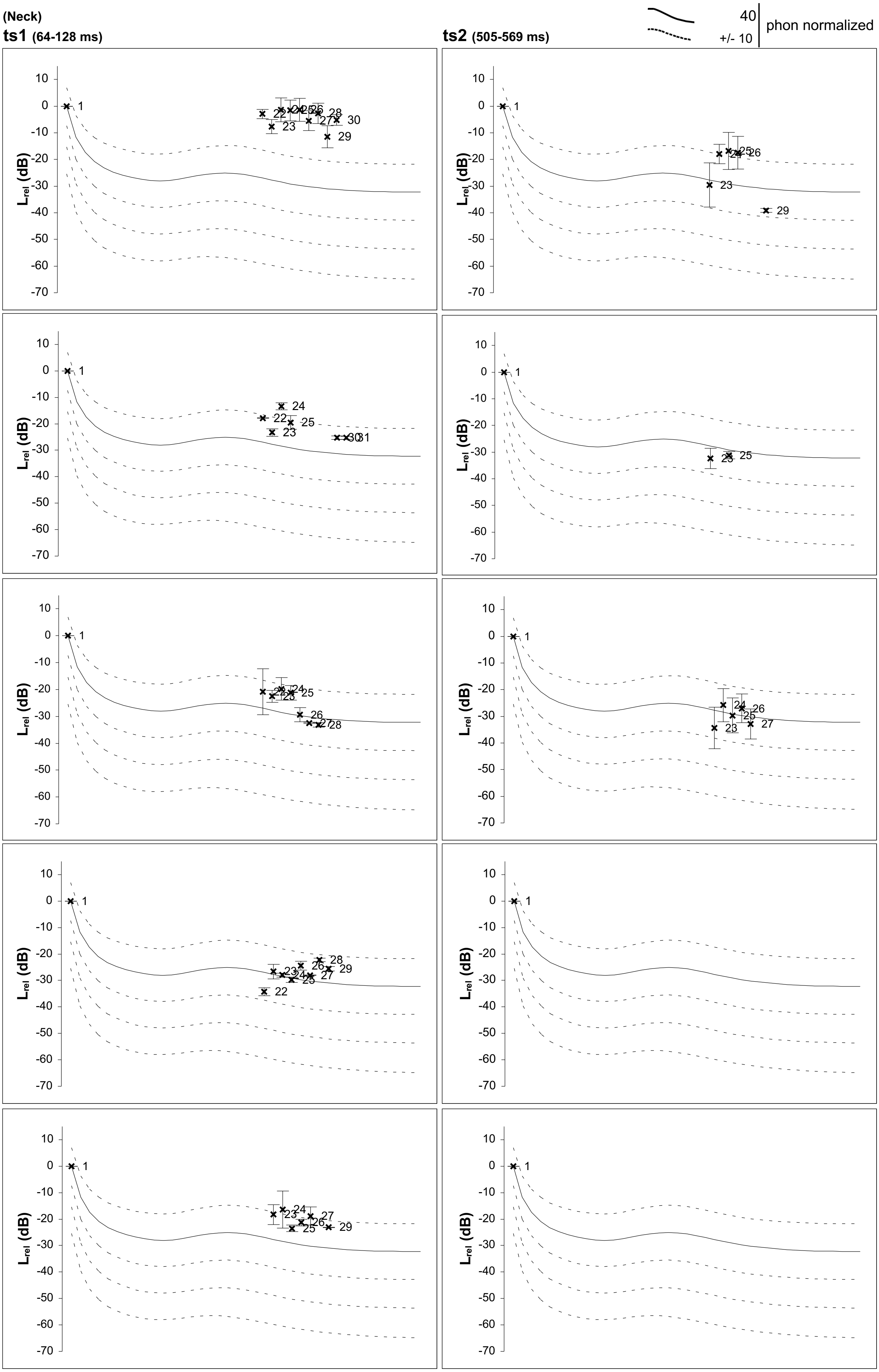
G1

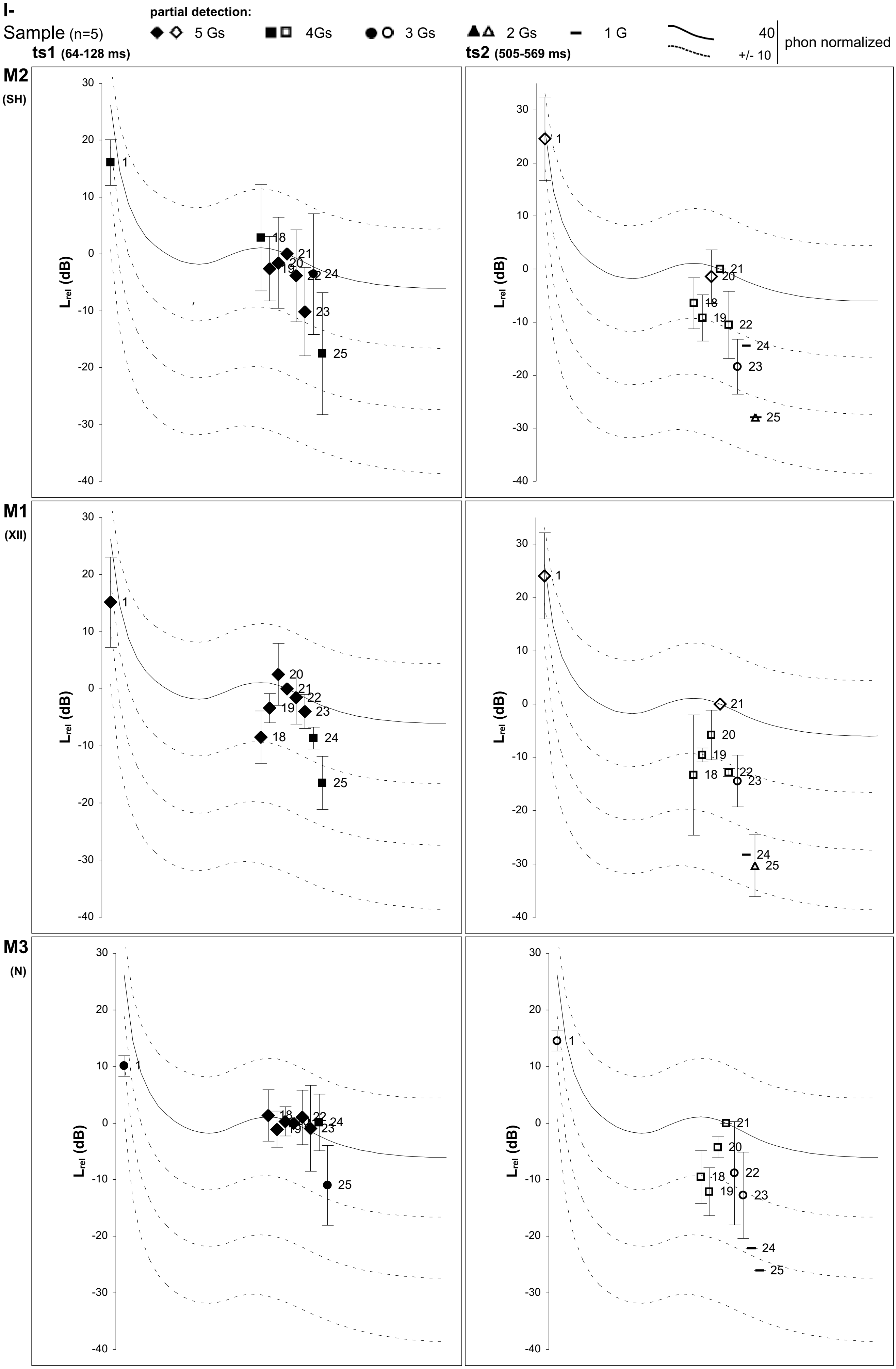
G2 (2Ts)

G3 (2Ts)

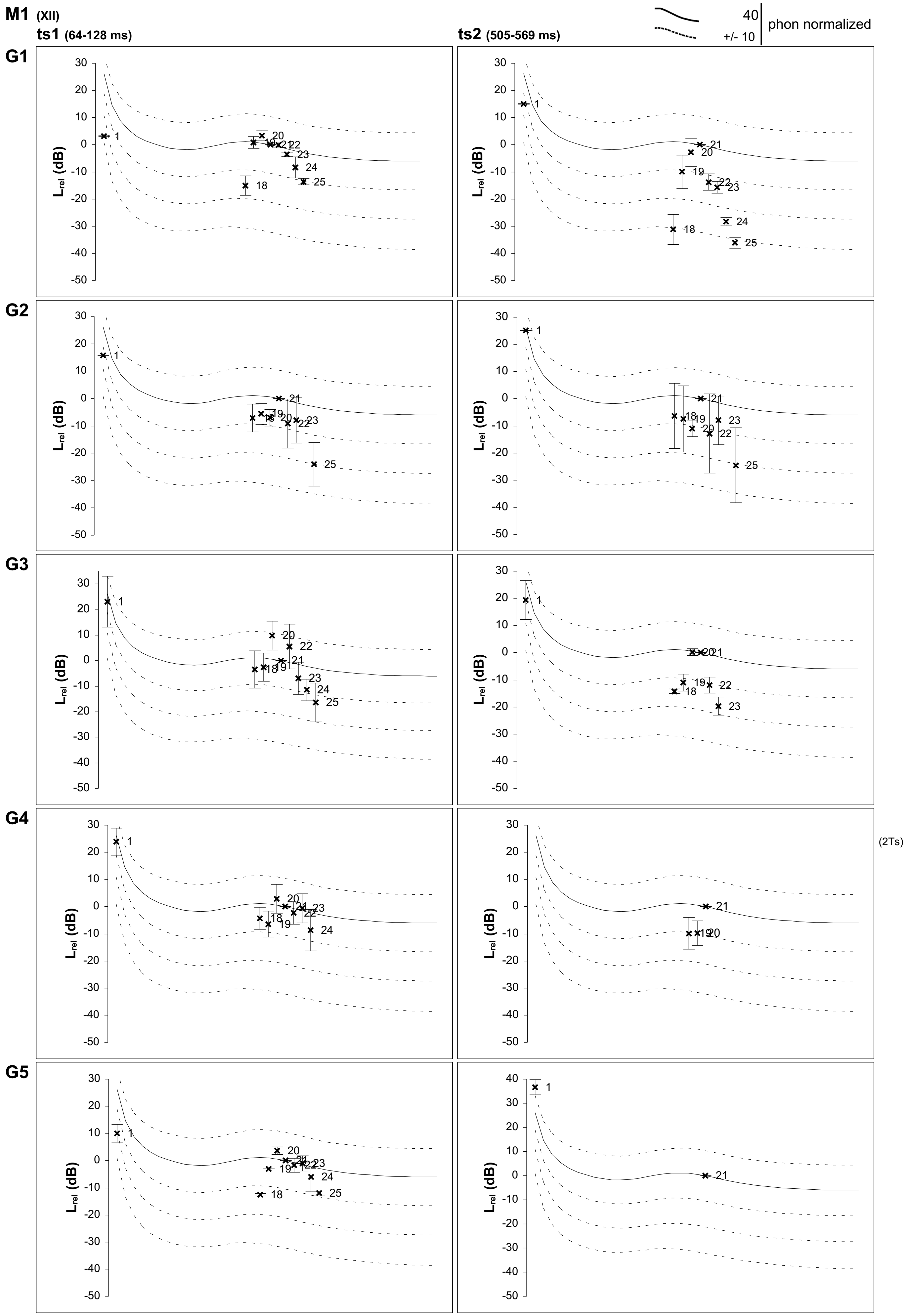
G4

G5




I-
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
Lrel (dB)

I-
M1 (XII)



ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
(2Ts)
L_{rel} (dB)

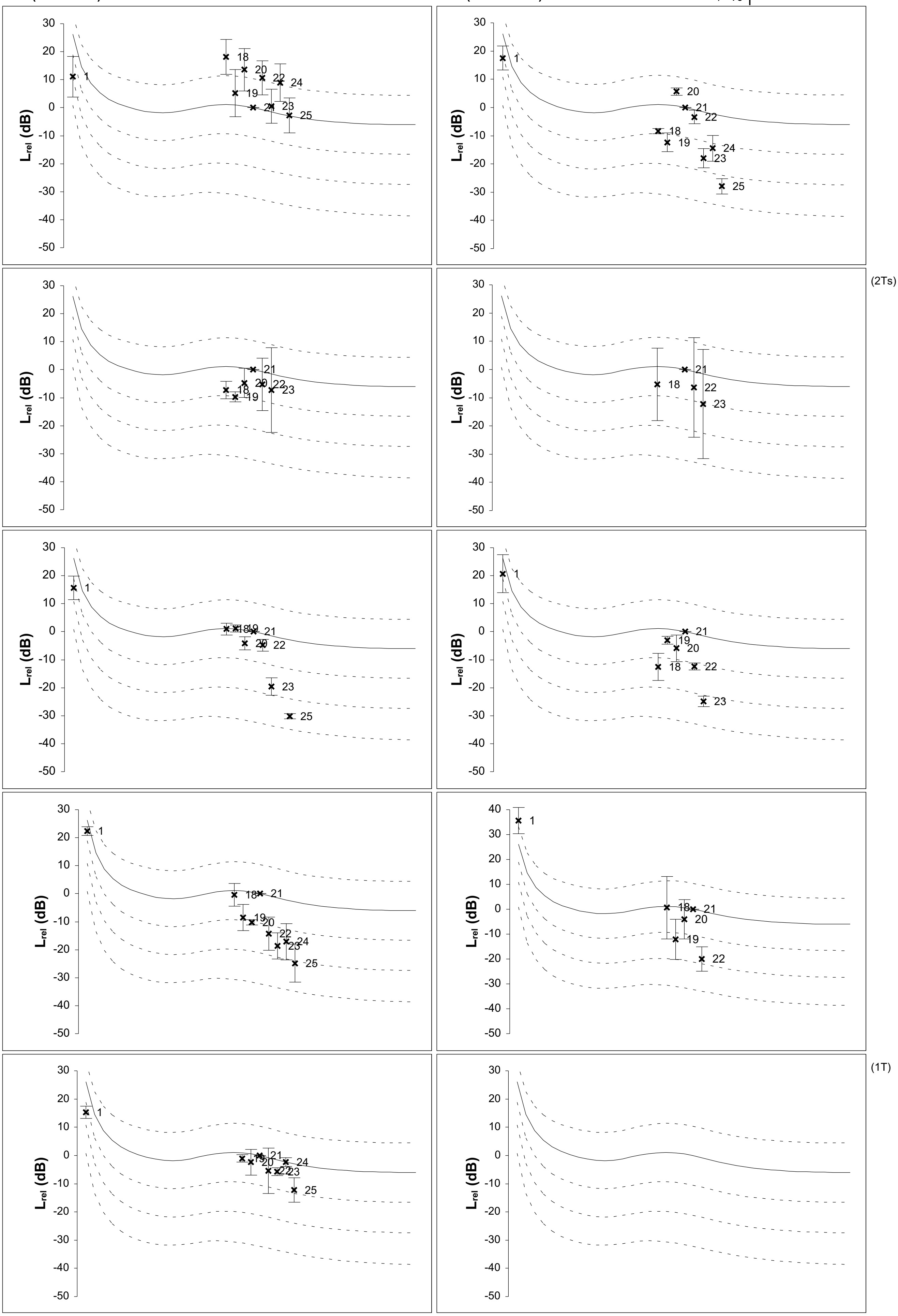
I-

M2 **(Sound hole)**

ts1 **(64-128 ms)** **ts2** **(505-569 ms)**

40 | +/- 10 — phon normalized

G1 **G2** (2Ts) **G3** **G4** **G5**



I-M3 (Neck)

40 | phon normalized
+/- 10 |

ts1 (64-128 ms) **ts2** (505-569 ms)

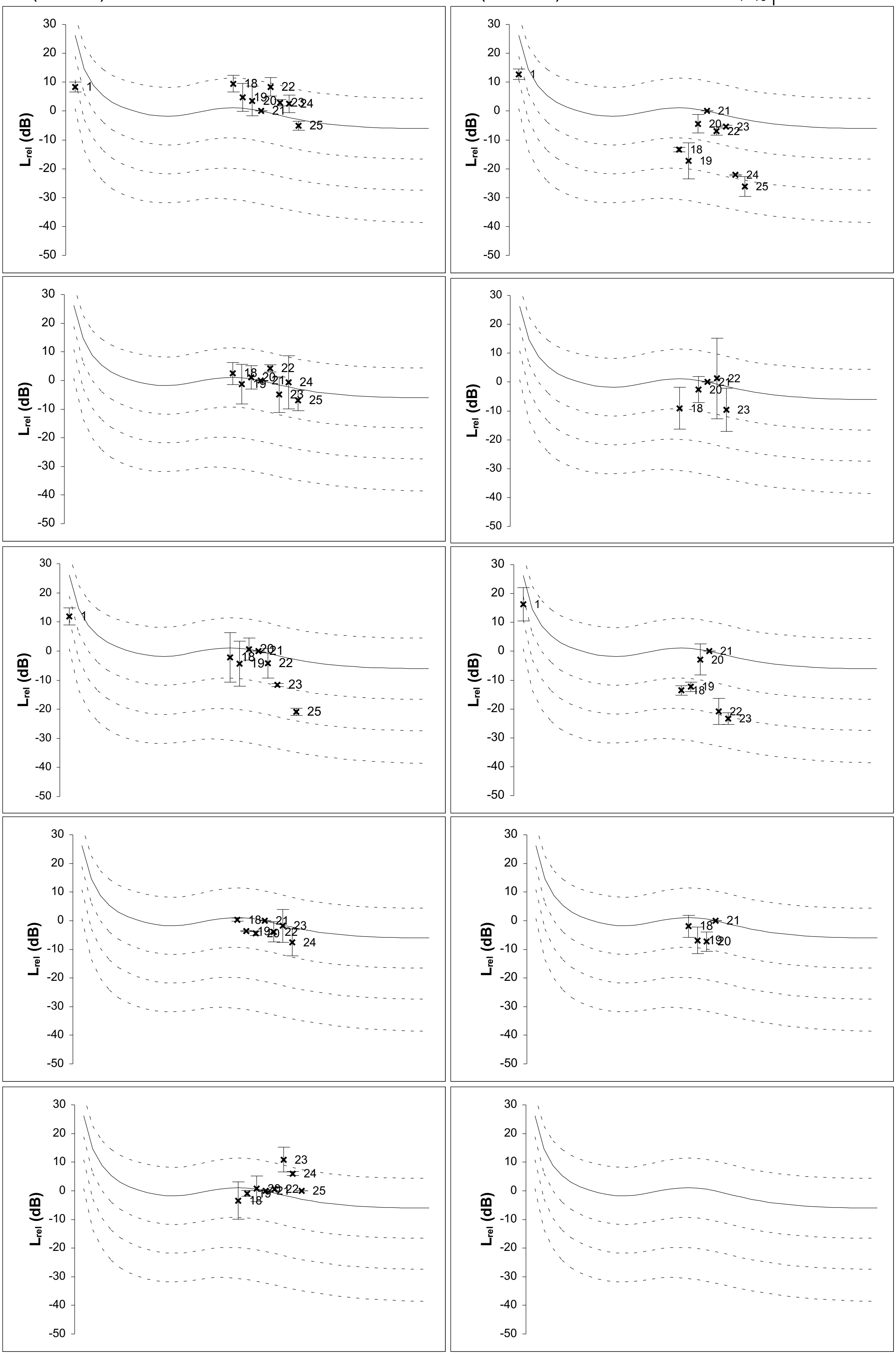
G1

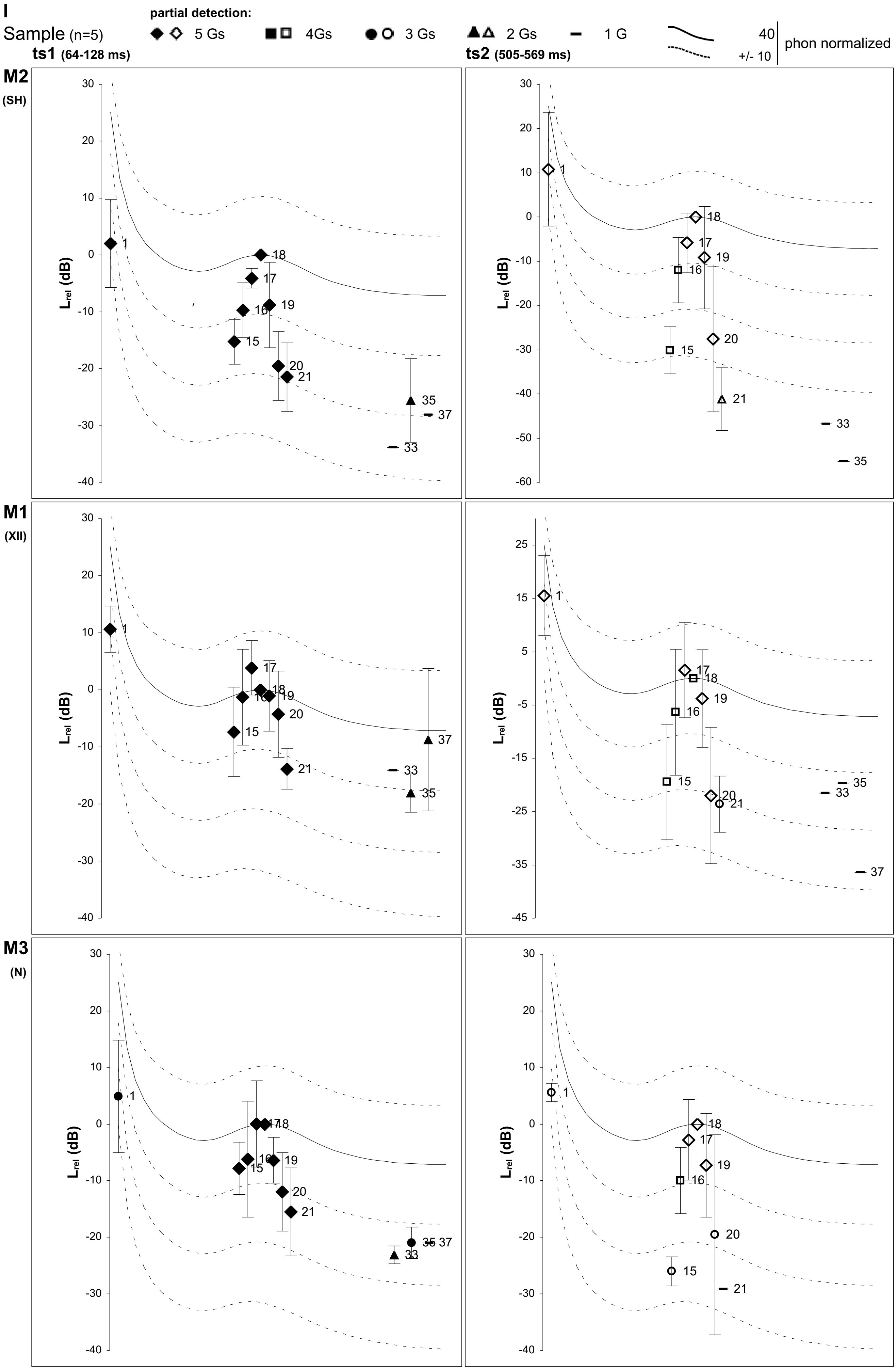
G2 (2Ts) (2Ts)

G3

G4 (2Ts) (2Ts)

G5 (1T)




I
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_{rel} (dB)

I

M1 (XII)

40 — +/- 10 — phon normalized

ts1 (64-128 ms) **ts2** (505-569 ms)

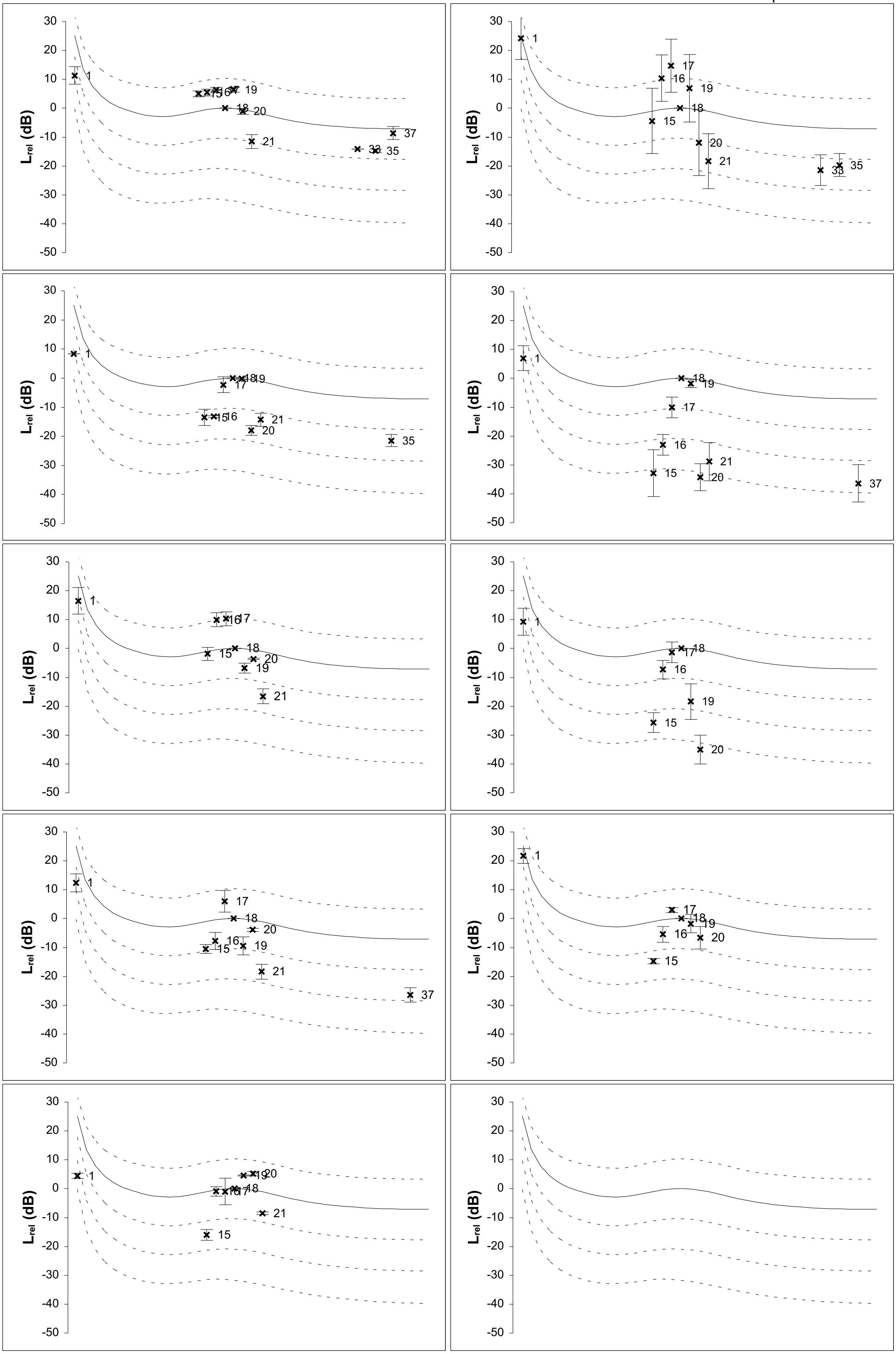
G1

G2

G3

G4

G5



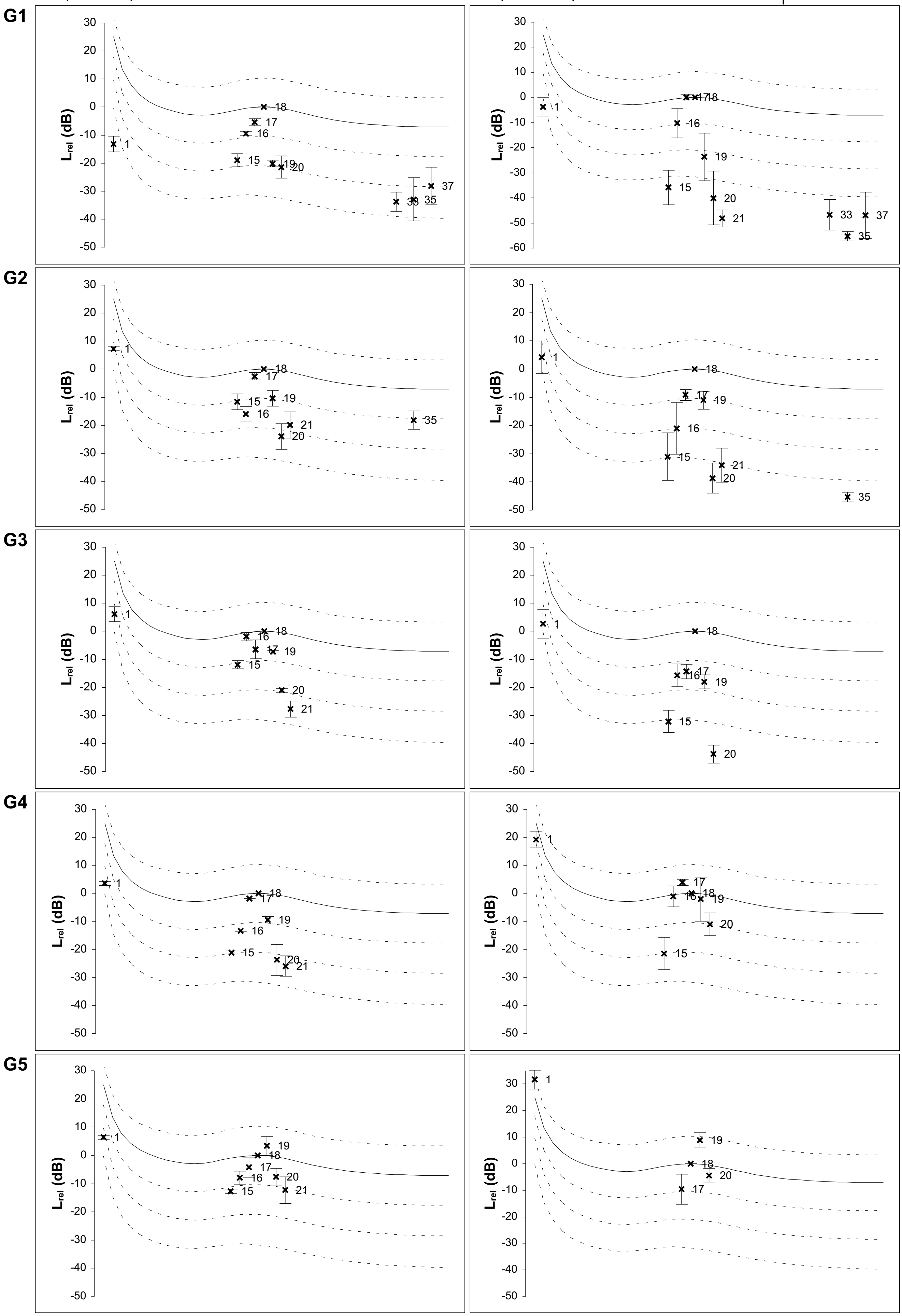
(1T)

I

M2 **(Sound hole)**

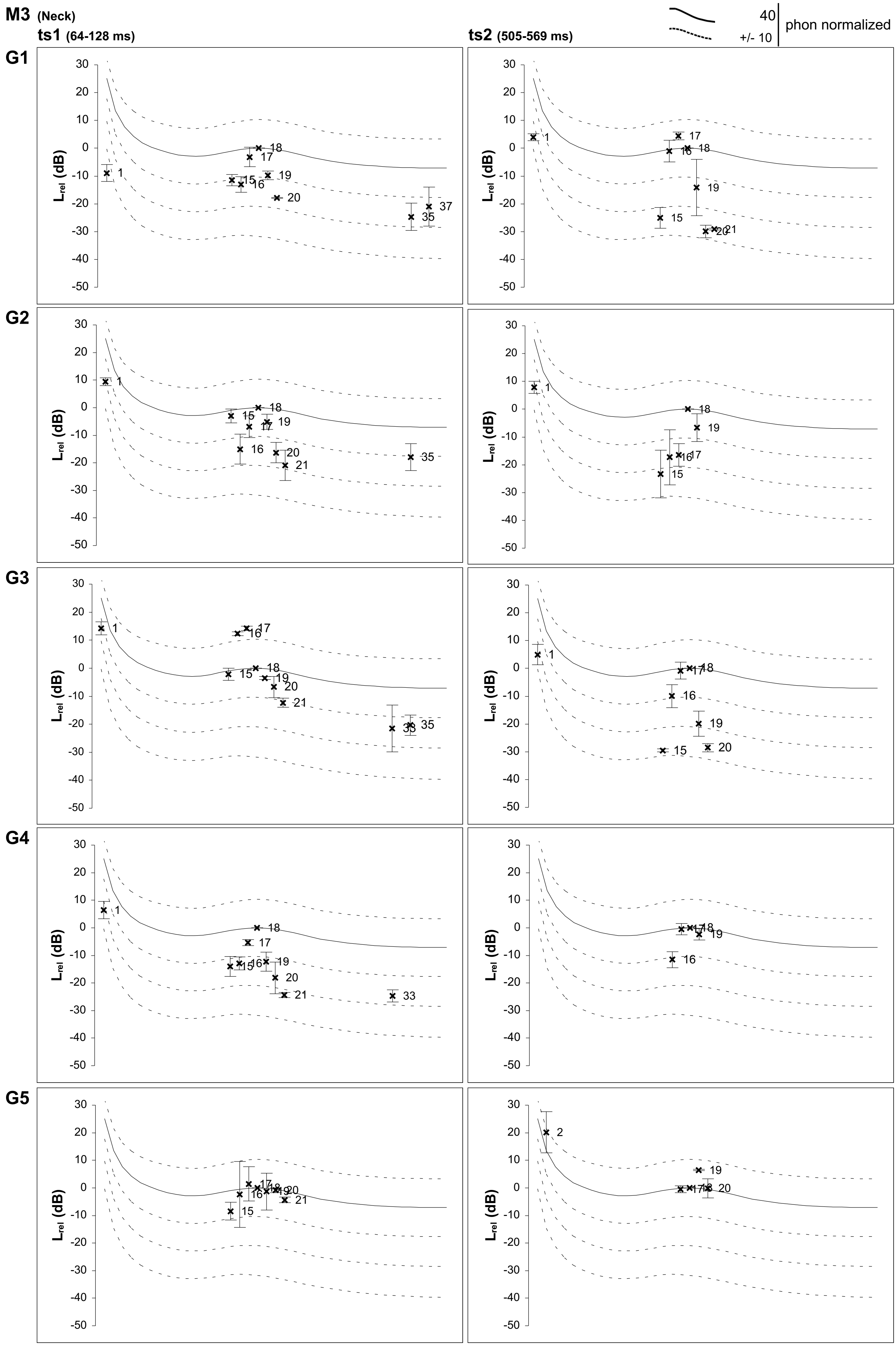
40 — phon normalized
+/- 10 — phon normalized

ts1 (64-128 ms) | **ts2 (505-569 ms)**

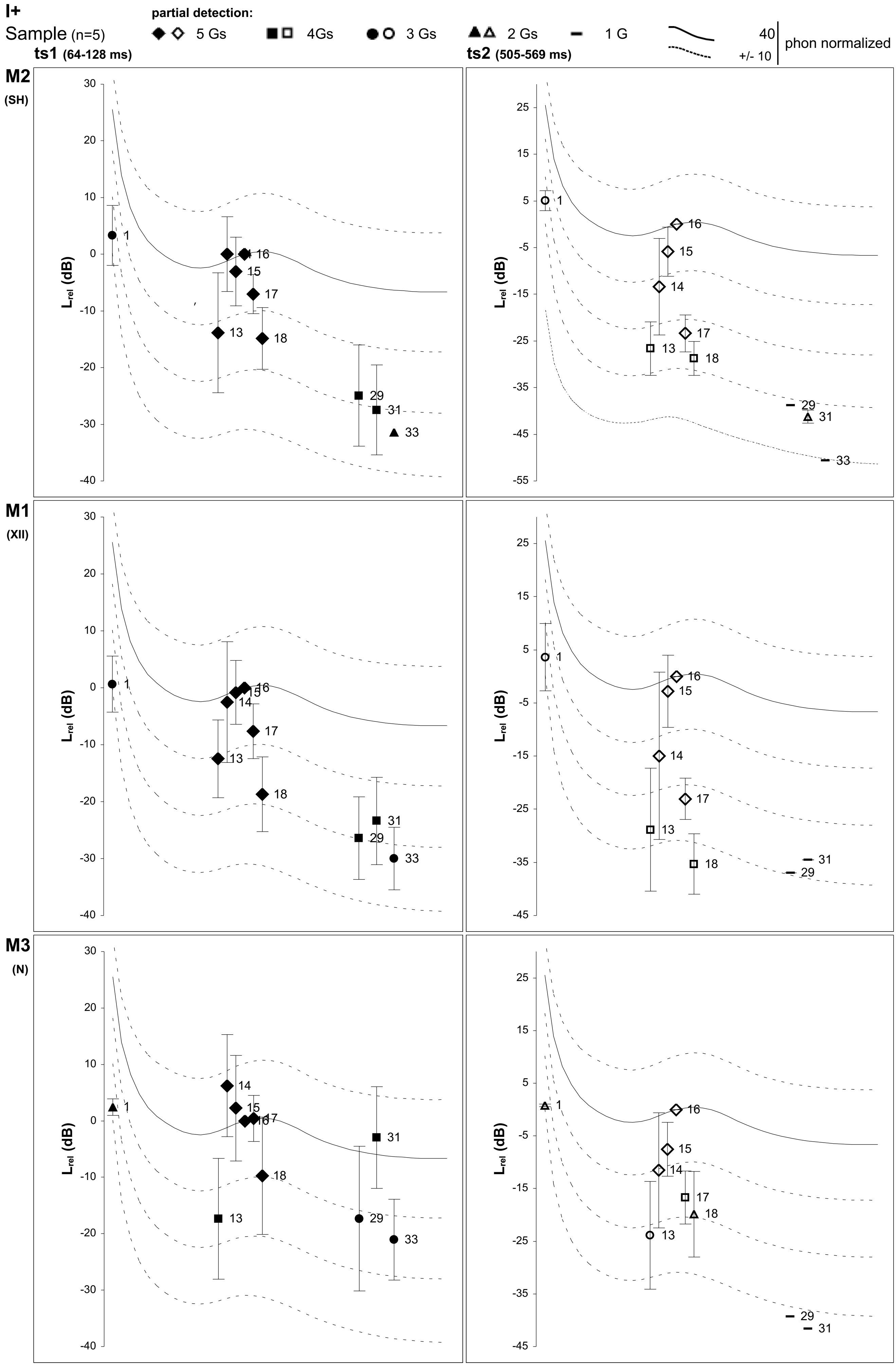


I

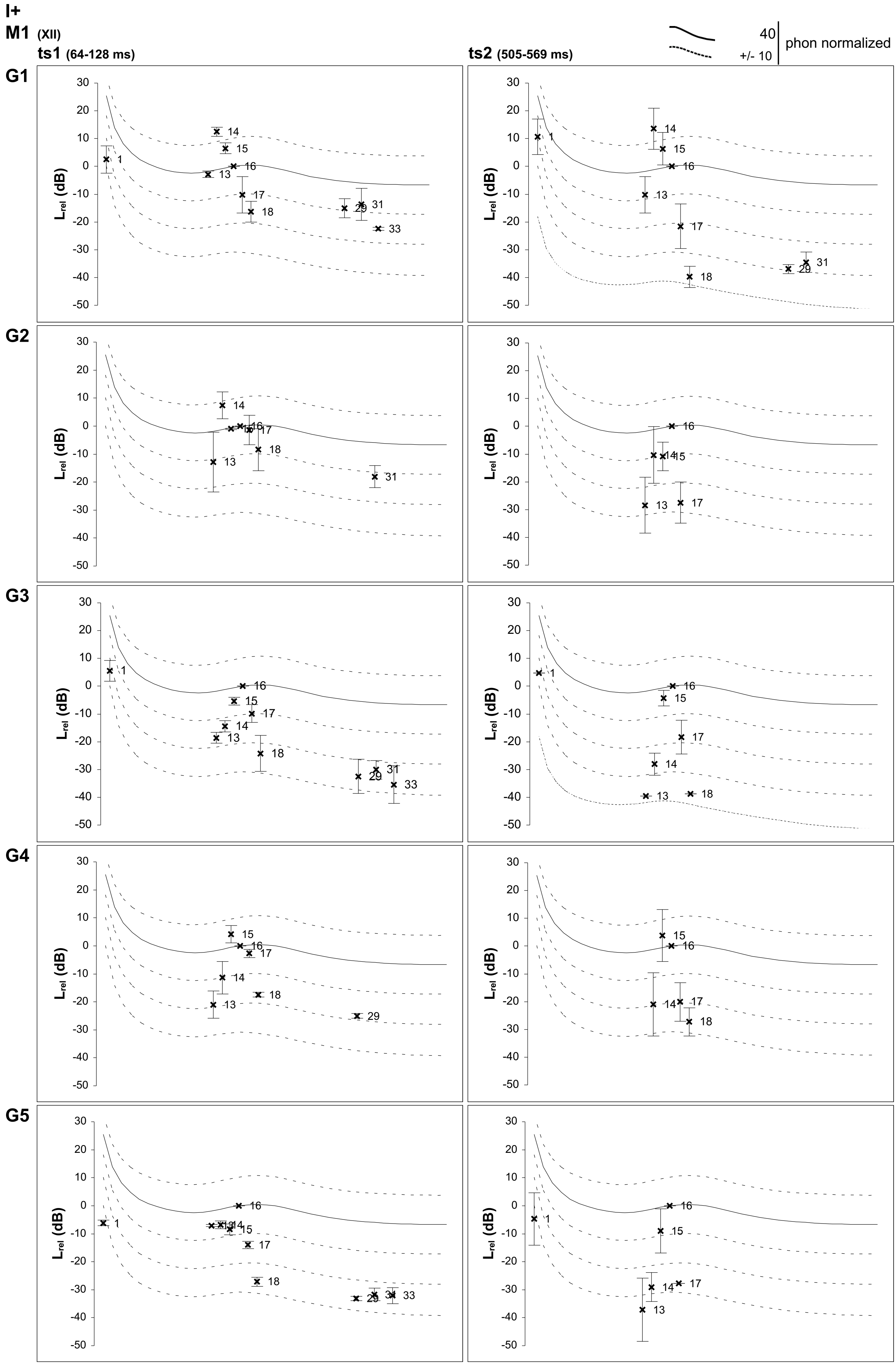
M3 (Neck)



ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
L_rel (dB)

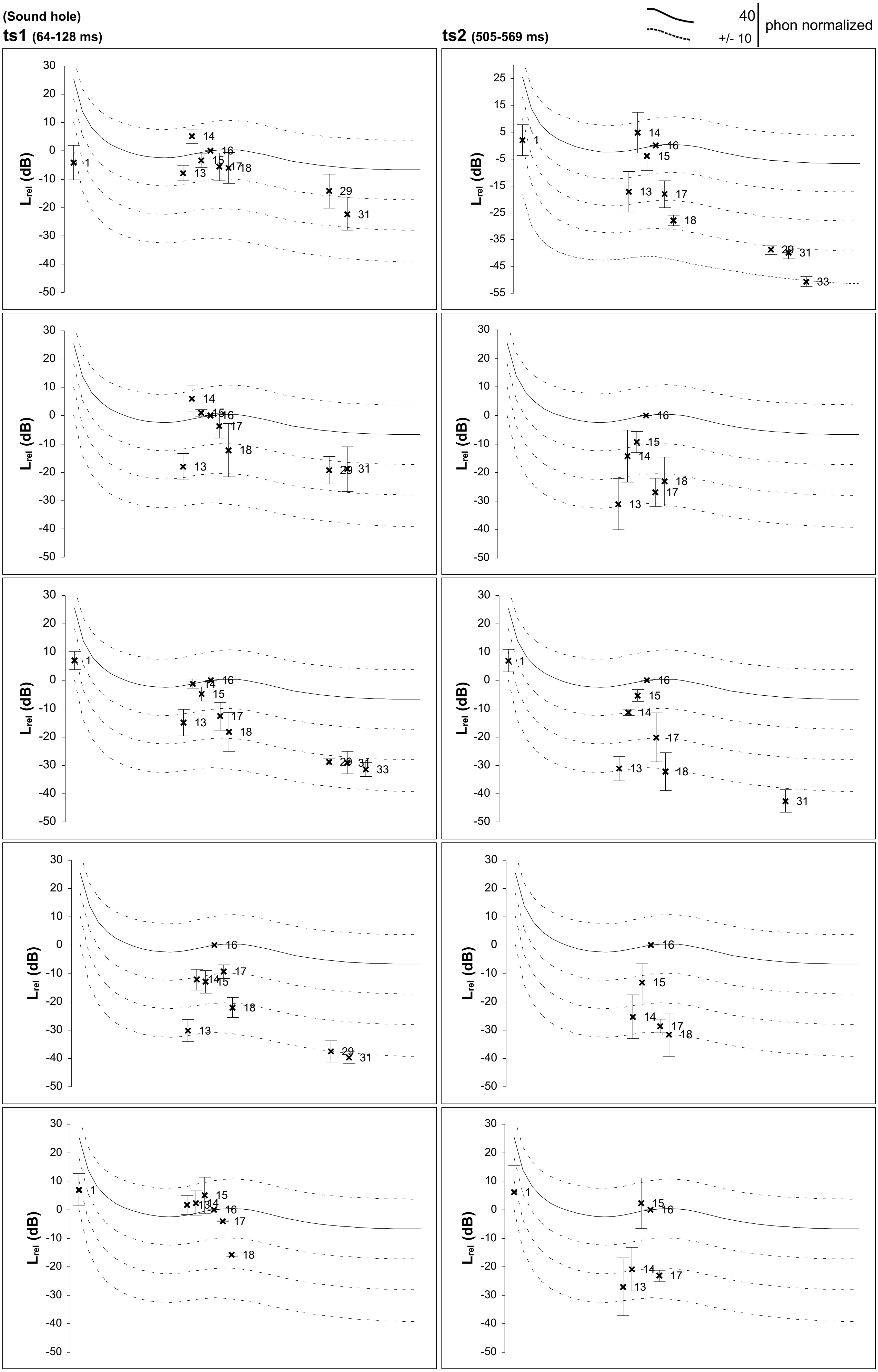


I+
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
Lrel (dB)


I+
M1 (XII)
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
L_rel (dB)

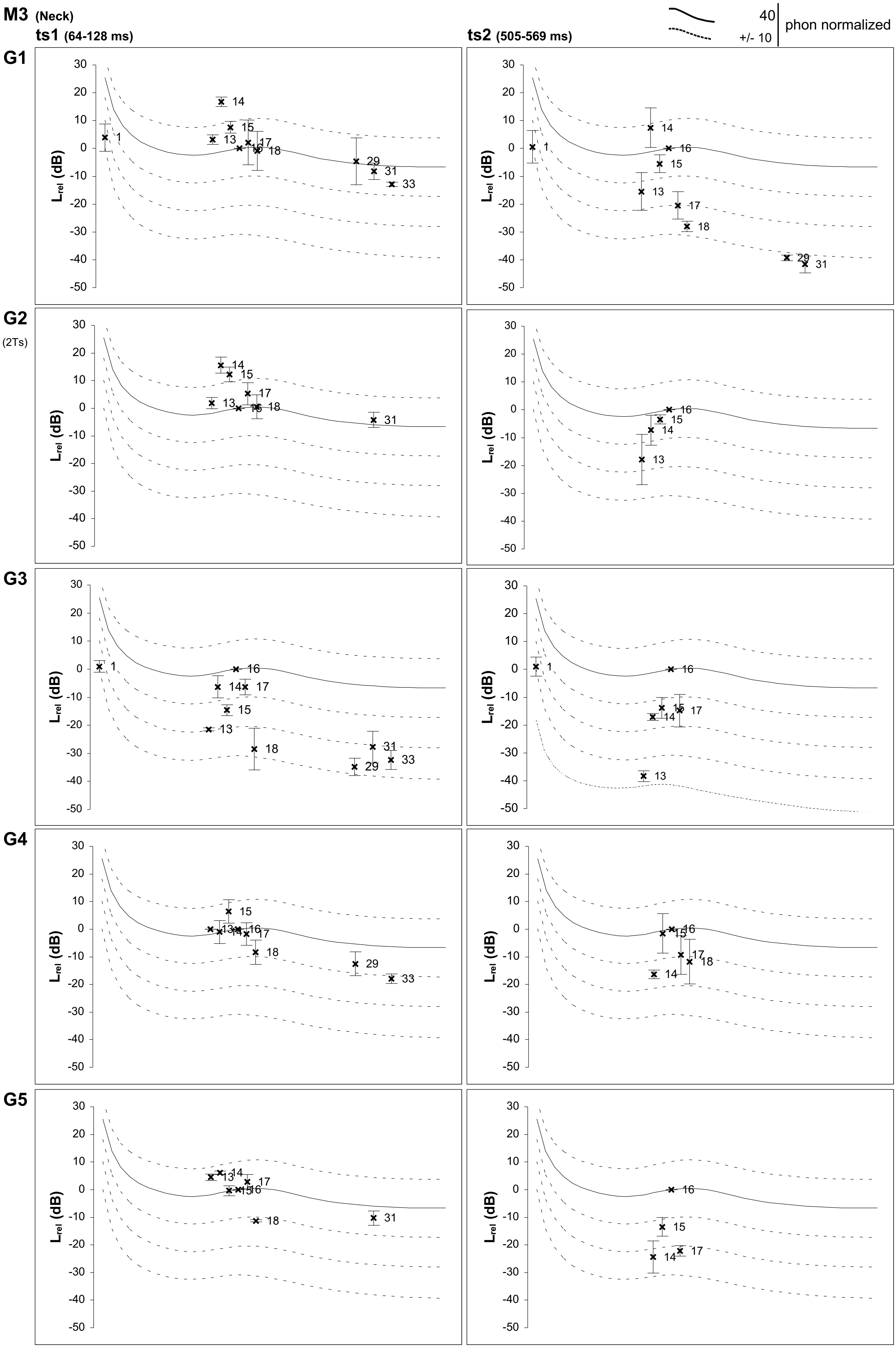
I+
M2 **(Sound hole)**
ts1 **(64-128 ms)** **ts2** **(505-569 ms)**

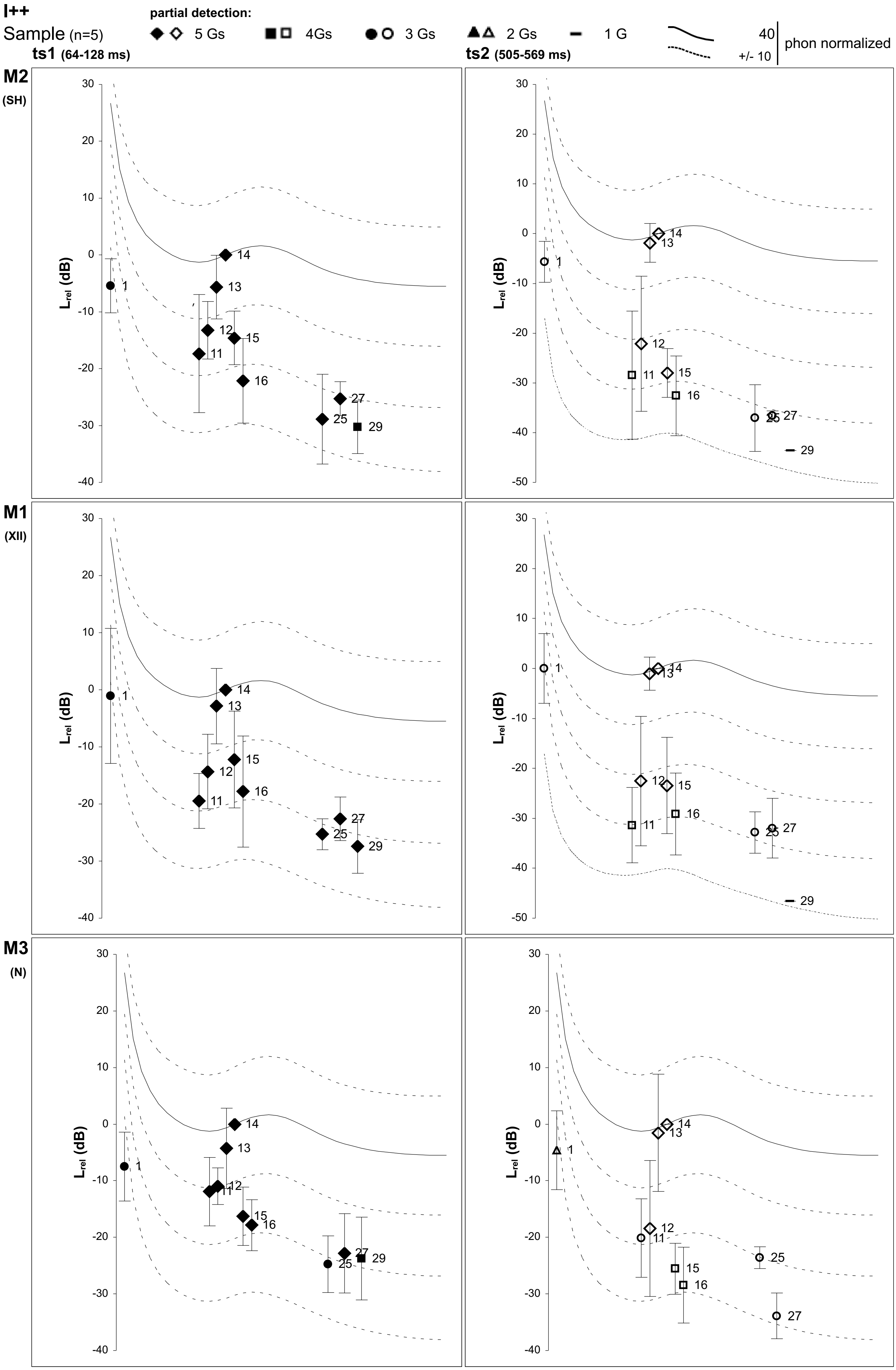
G1 G2 G3 G4 G5



I+

M3 (Neck)

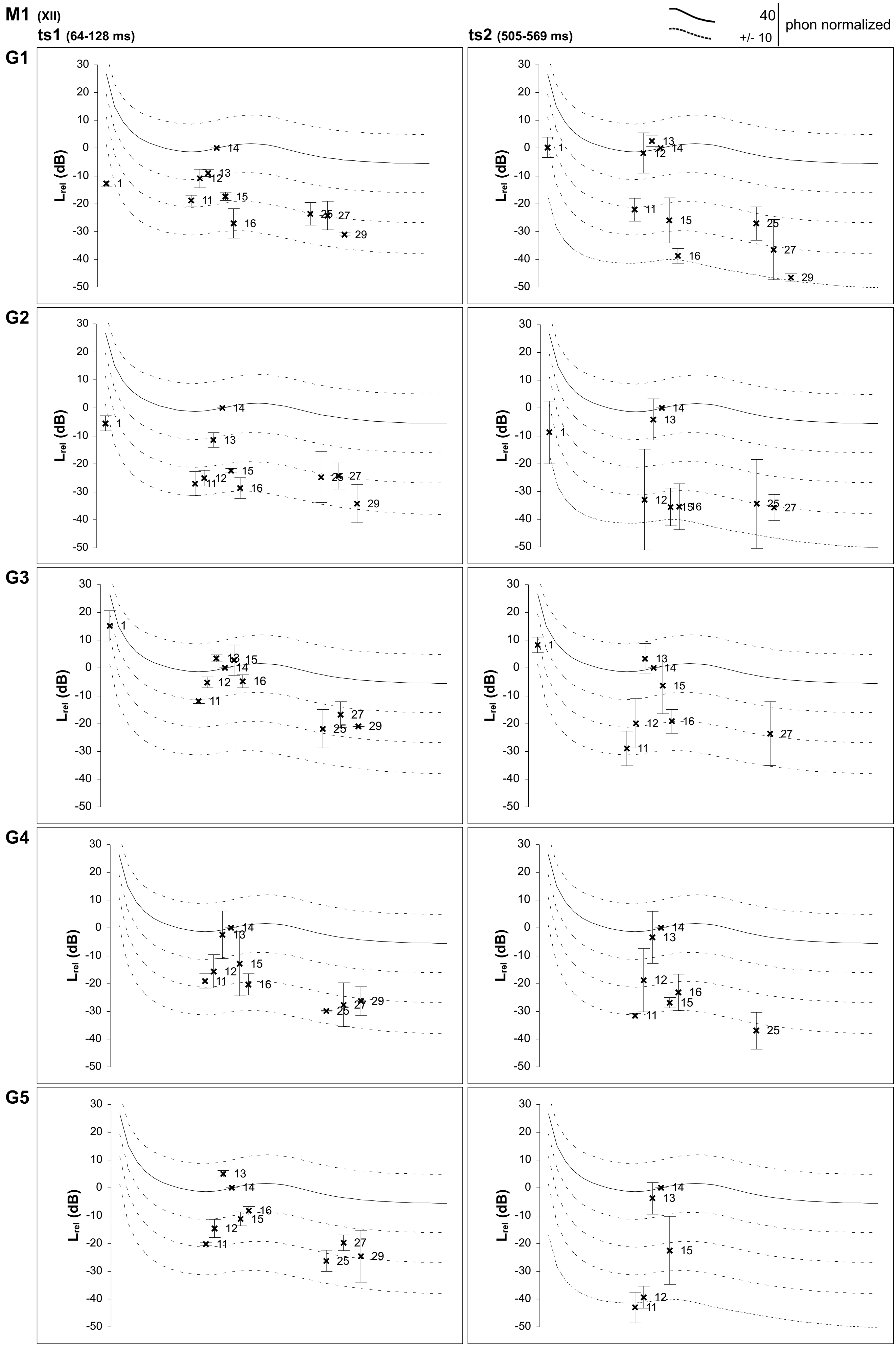

ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
(2Ts)
G3
G4
G5
L_{rel} (dB)


I++
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_{rel} (dB)

I++

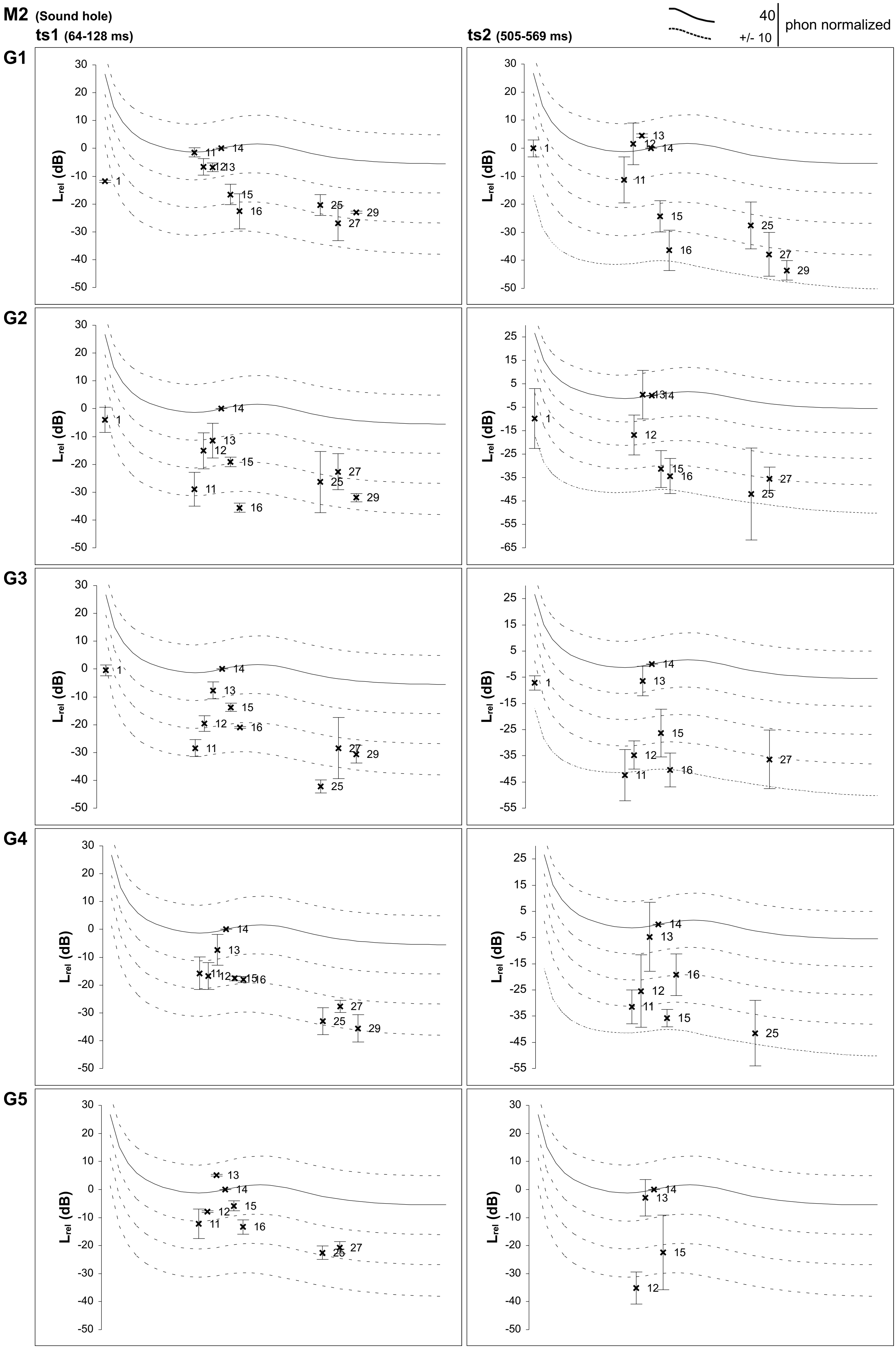
M1 (XII)

ts1 (64-128 ms) **ts2** (505-569 ms)



I++

M2 (Sound hole)



I++

M3 **(Neck)**

ts1 **(64-128 ms)** **ts2** **(505-569 ms)**

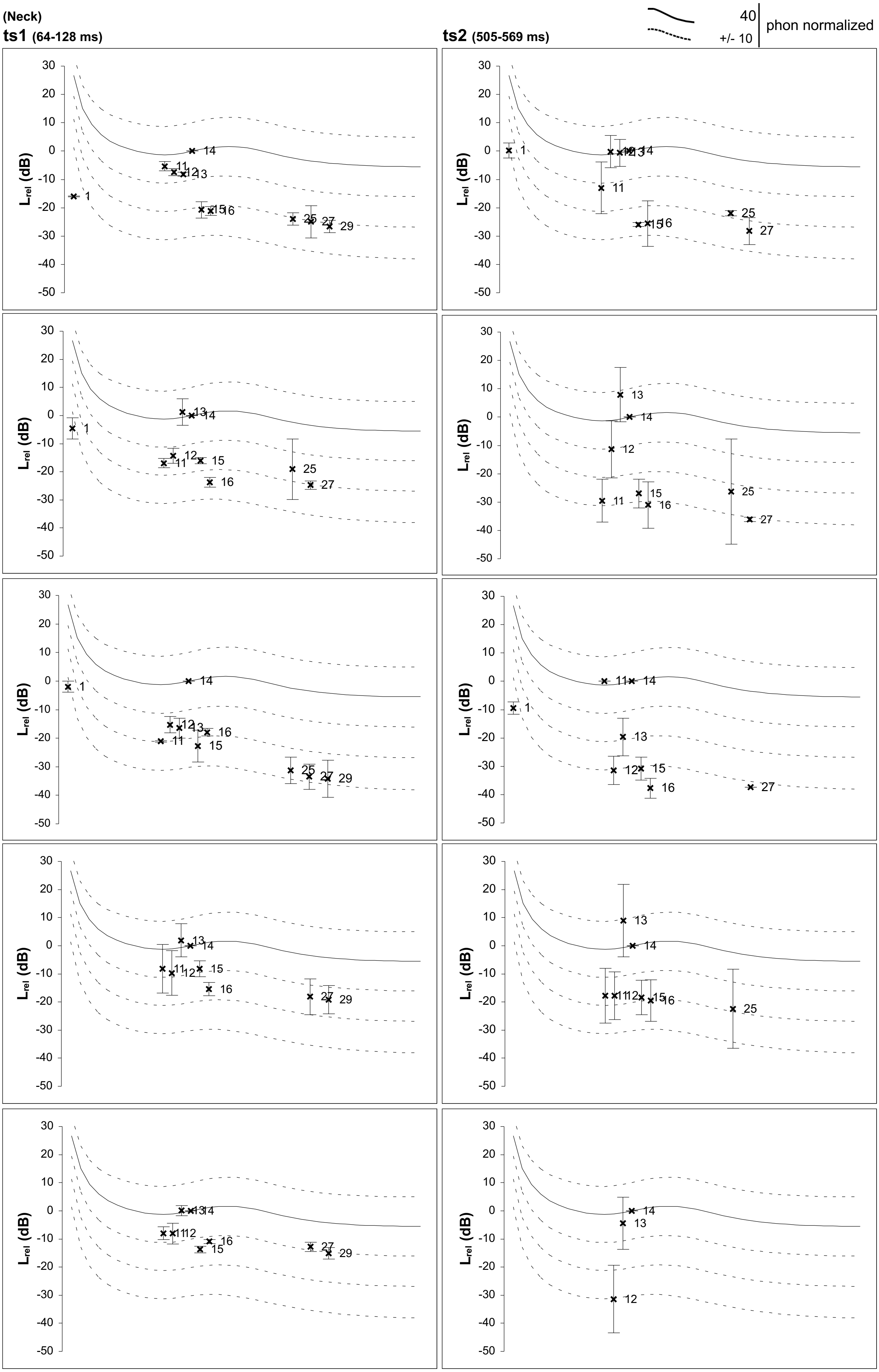
G1

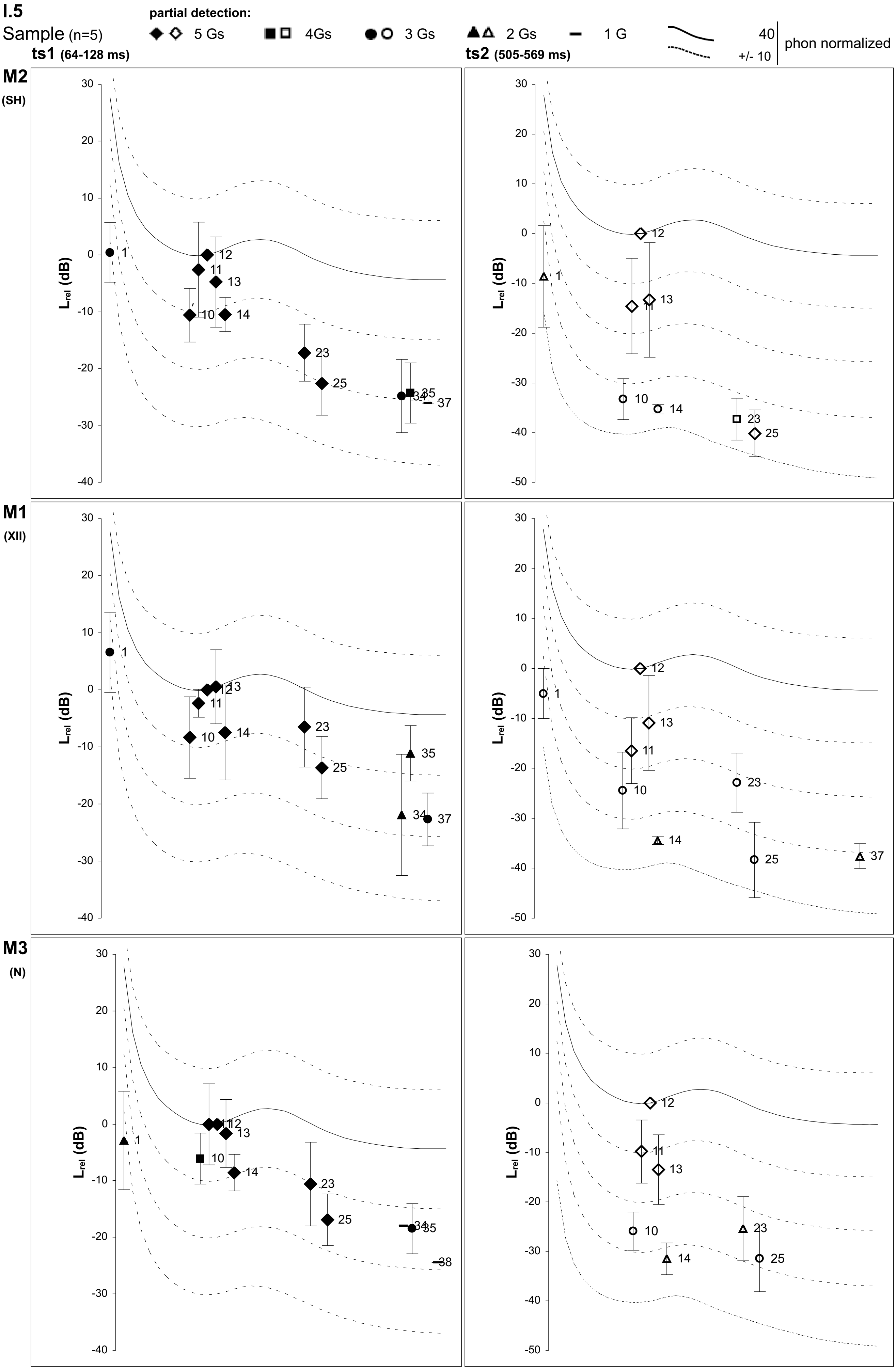
G2

G3

G4

G5

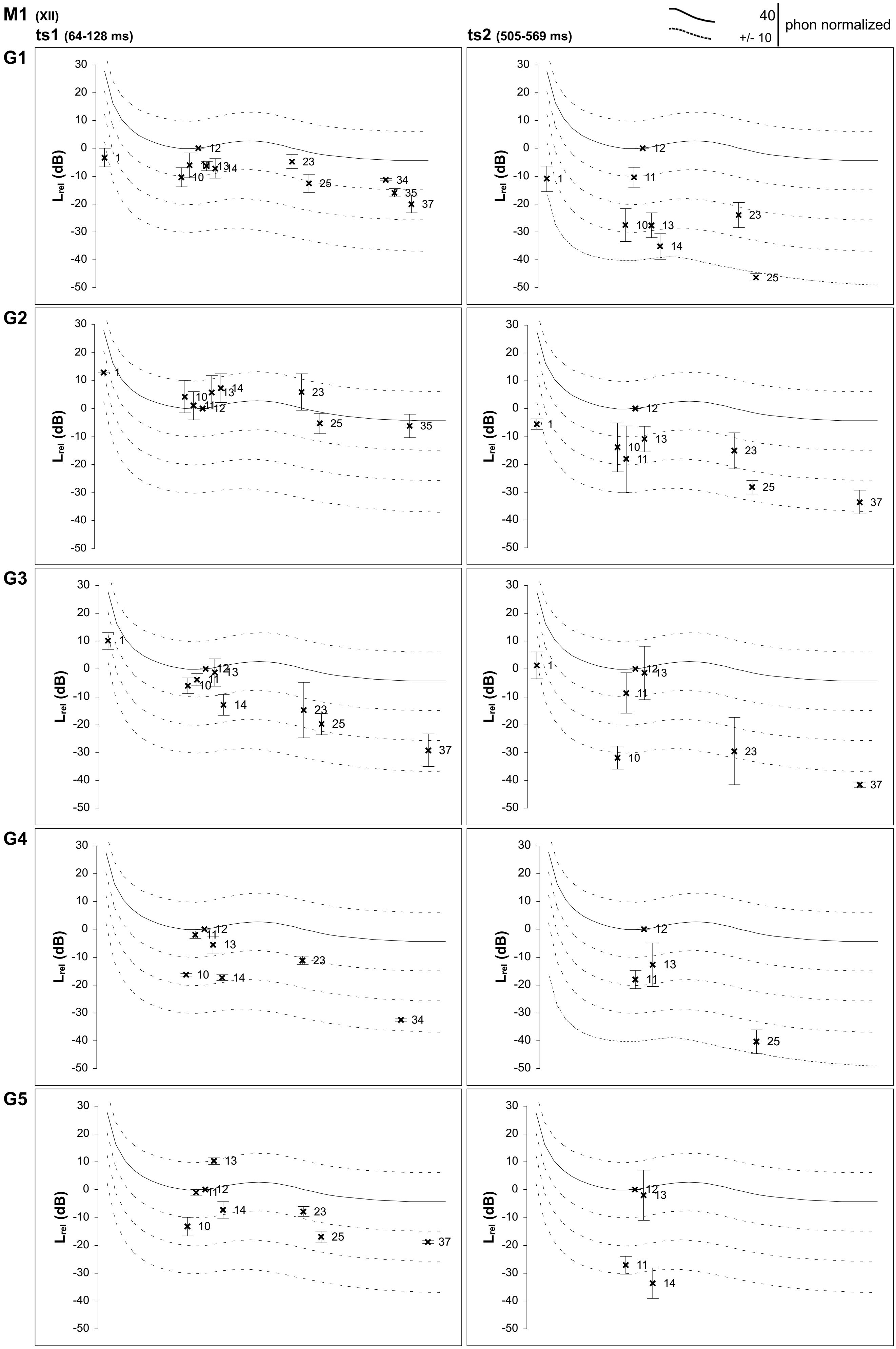




I.5
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_rel (dB)

I.5

M1 (XII)



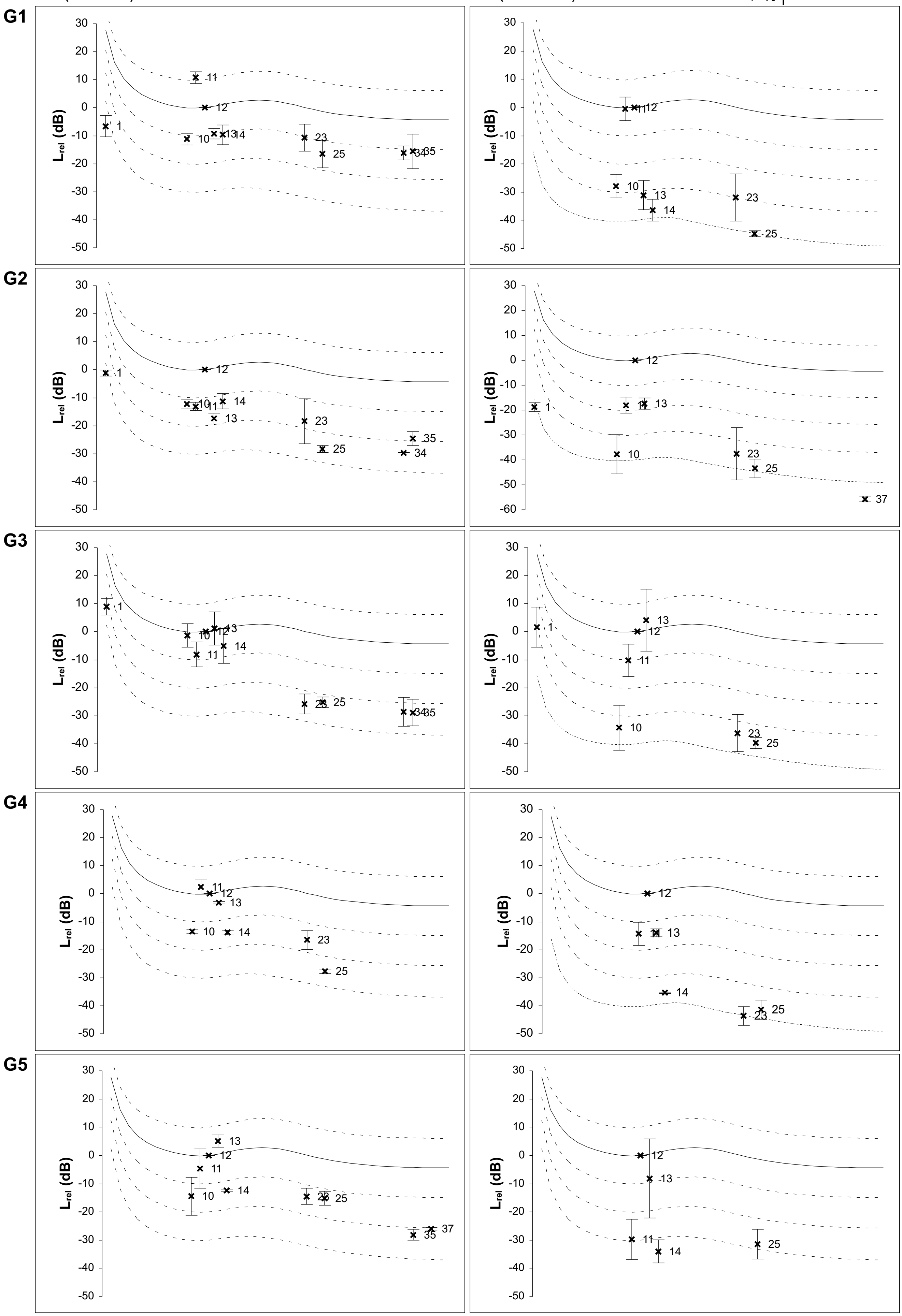
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
L_rel (dB)

I.5

M2 (Sound hole)

ts1 (64-128 ms) **ts2** (505-569 ms)

40 | phon normalized
+/- 10



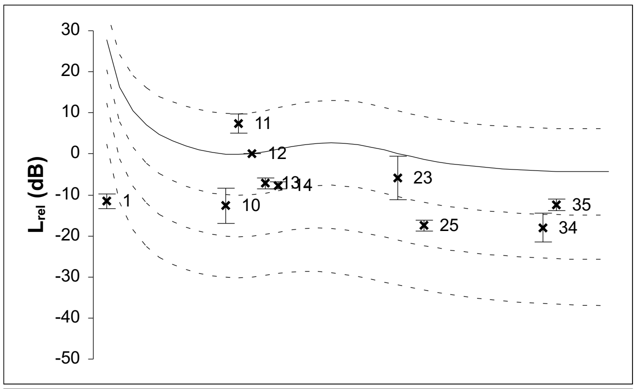
I.5

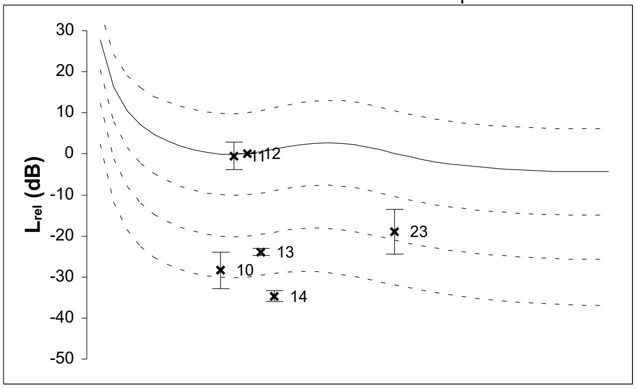
M3 **(Neck)**

40 | phon normalized
+/- 10

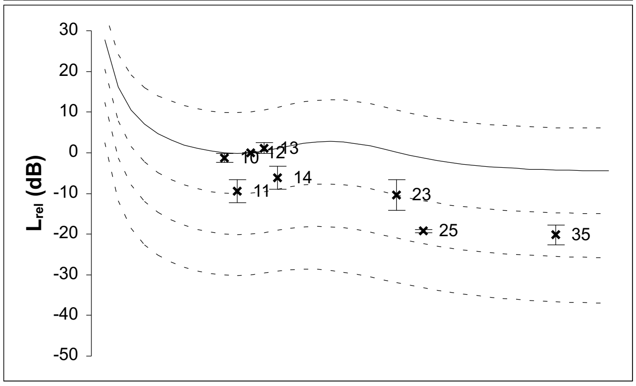
ts1 **(64-128 ms)** **ts2** **(505-569 ms)**

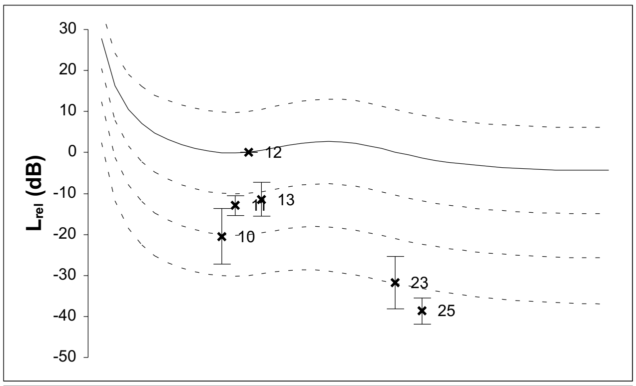
G1



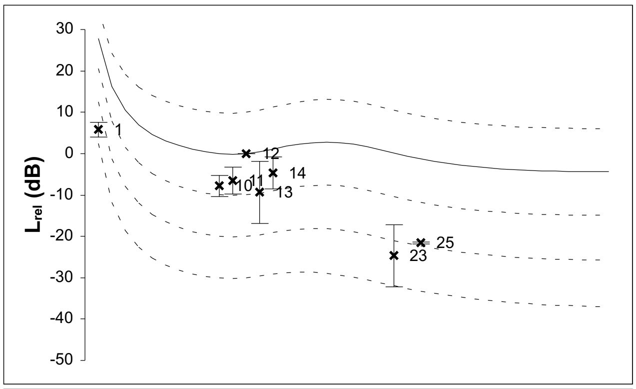


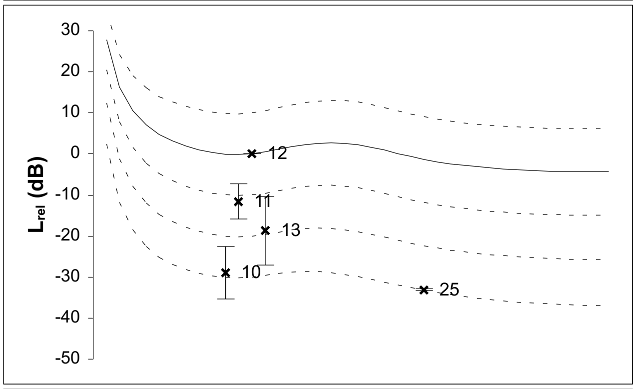
G2



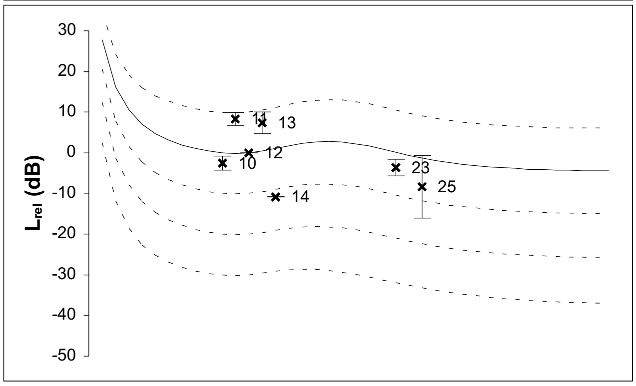


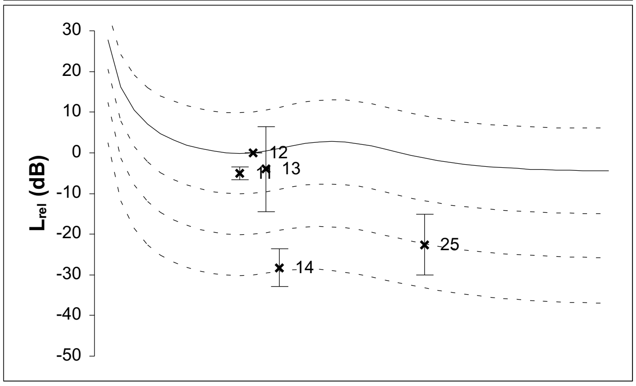
G3



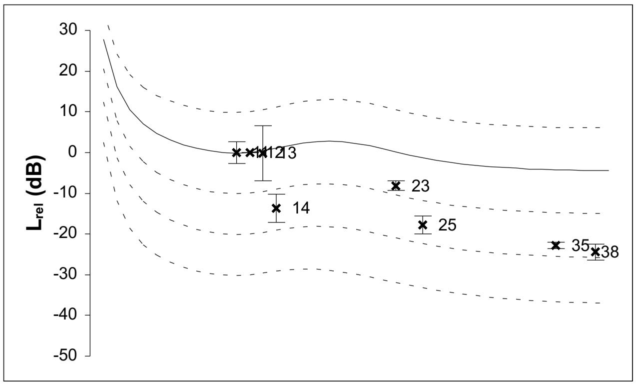


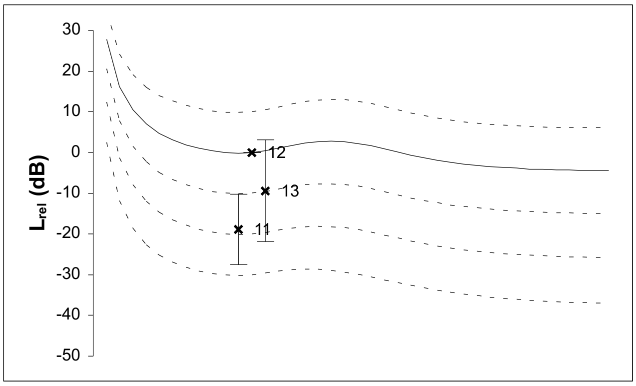
G4

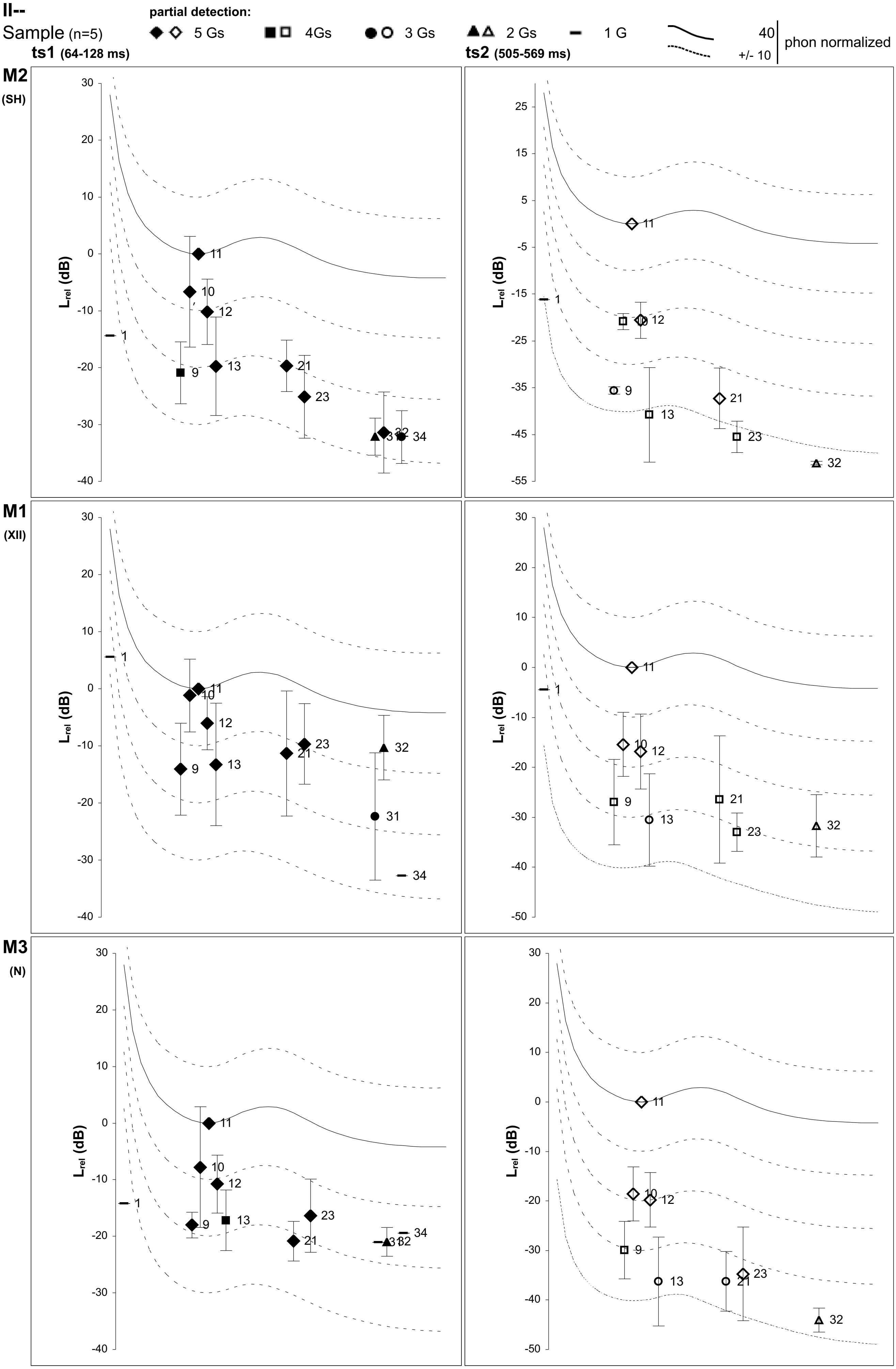




G5







II--
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
Lrel (dB)

II--

M1 (XII)

ts1 (64-128 ms) **ts2** (505-569 ms)

40 | +/- 10 | phon normalized

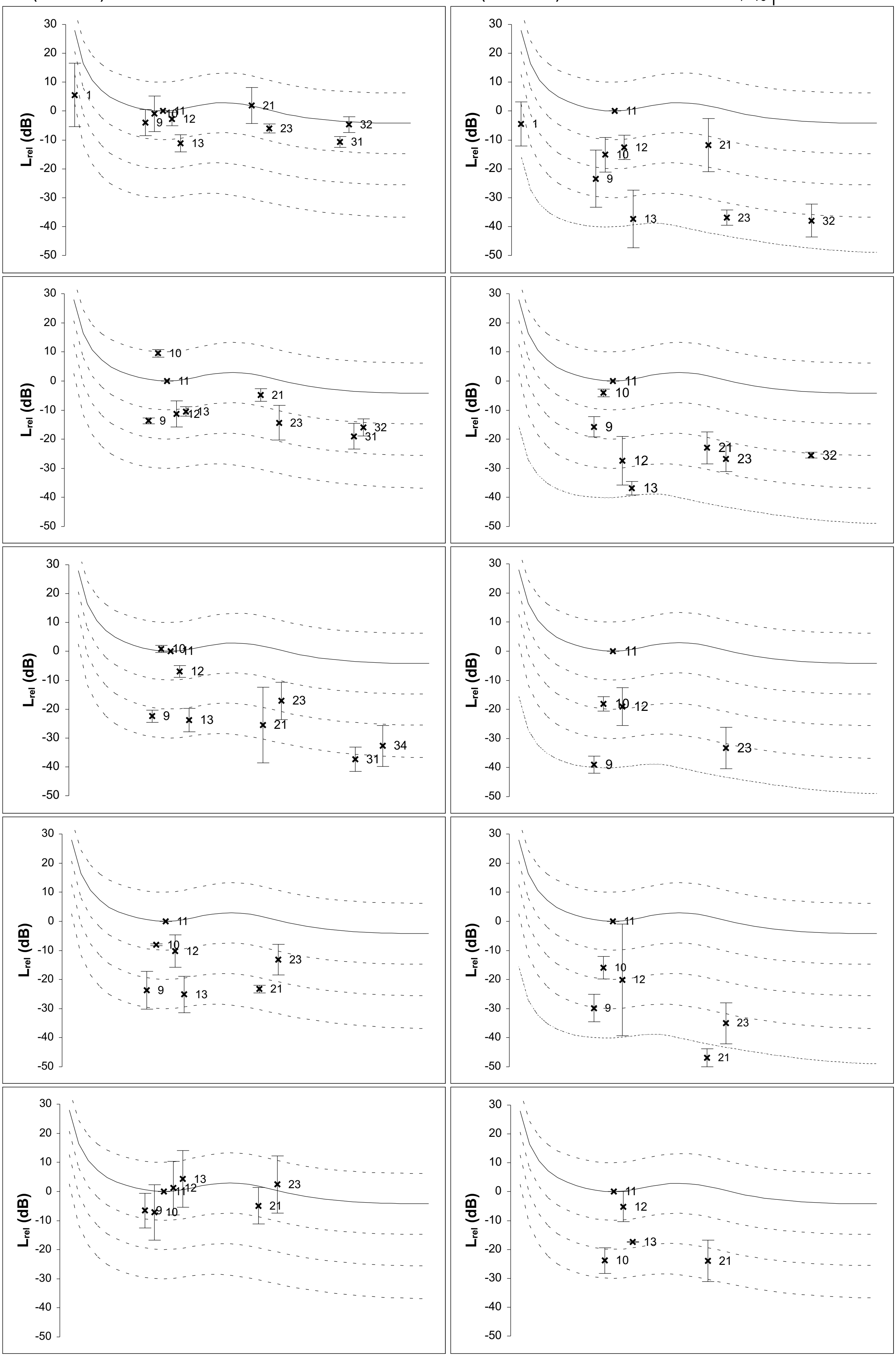
G1

G2

G3

G4

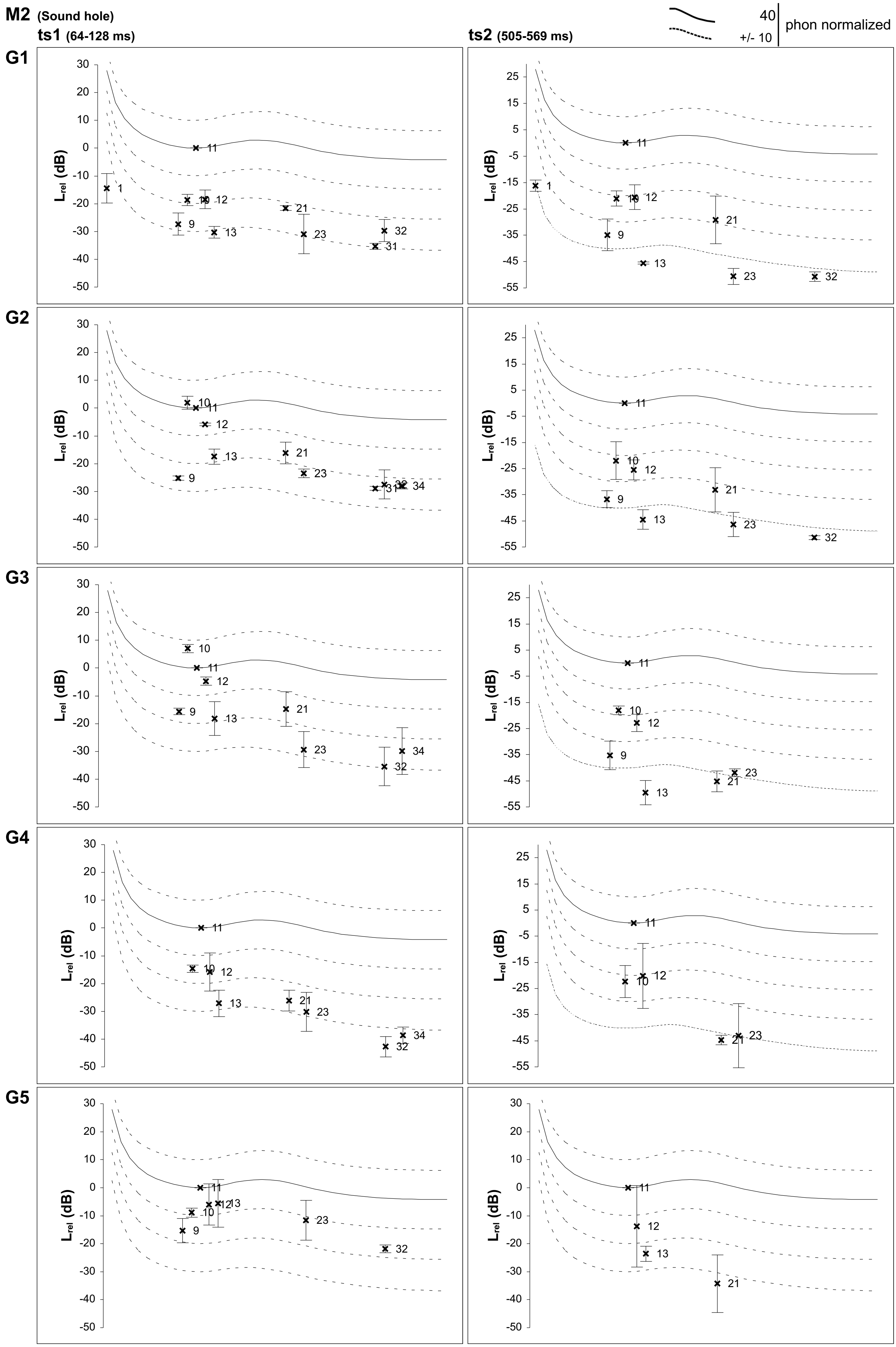
G5



II--

M2 **(Sound hole)**

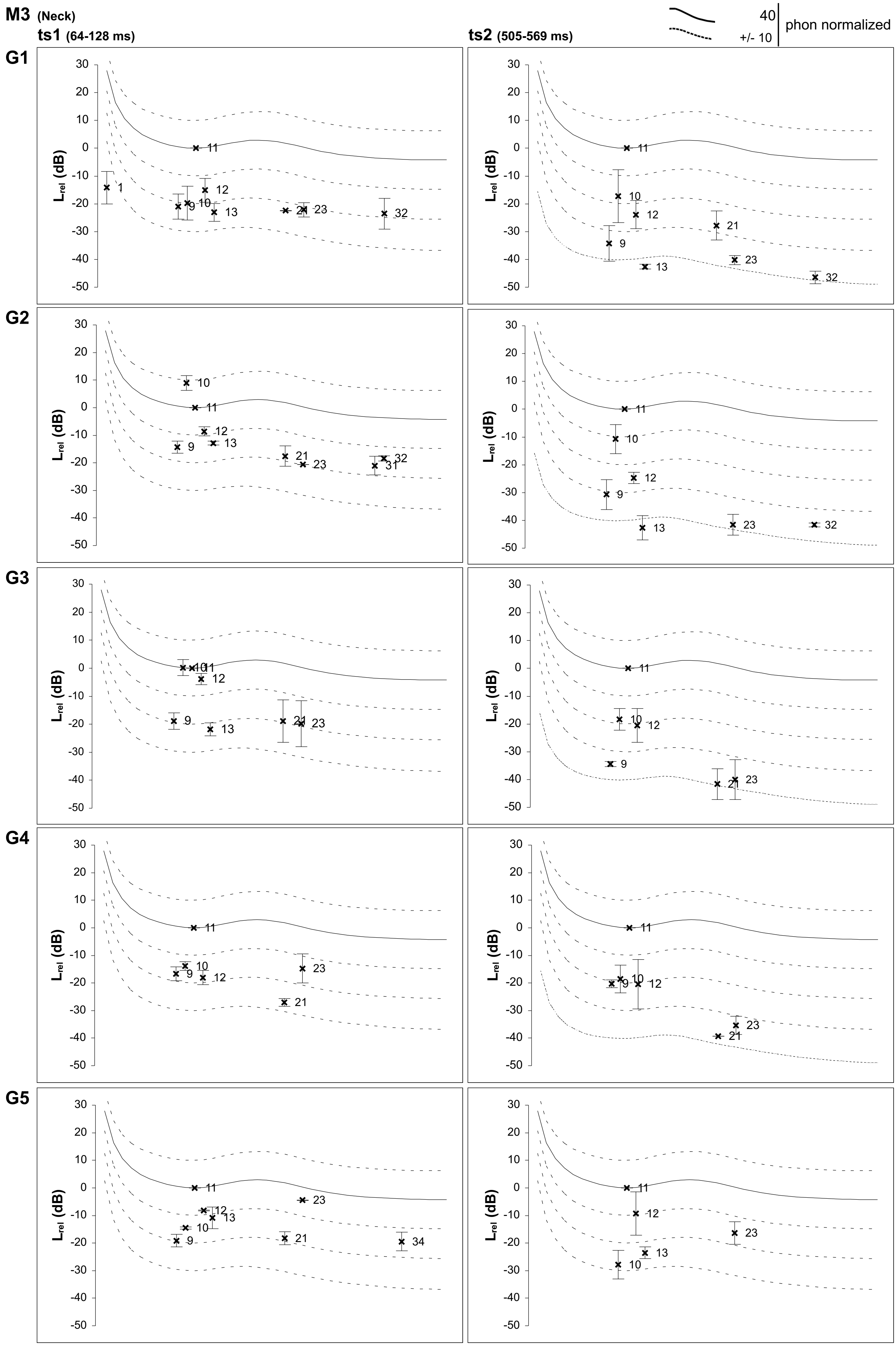
ts1 **(64-128 ms)** **ts2** **(505-569 ms)**

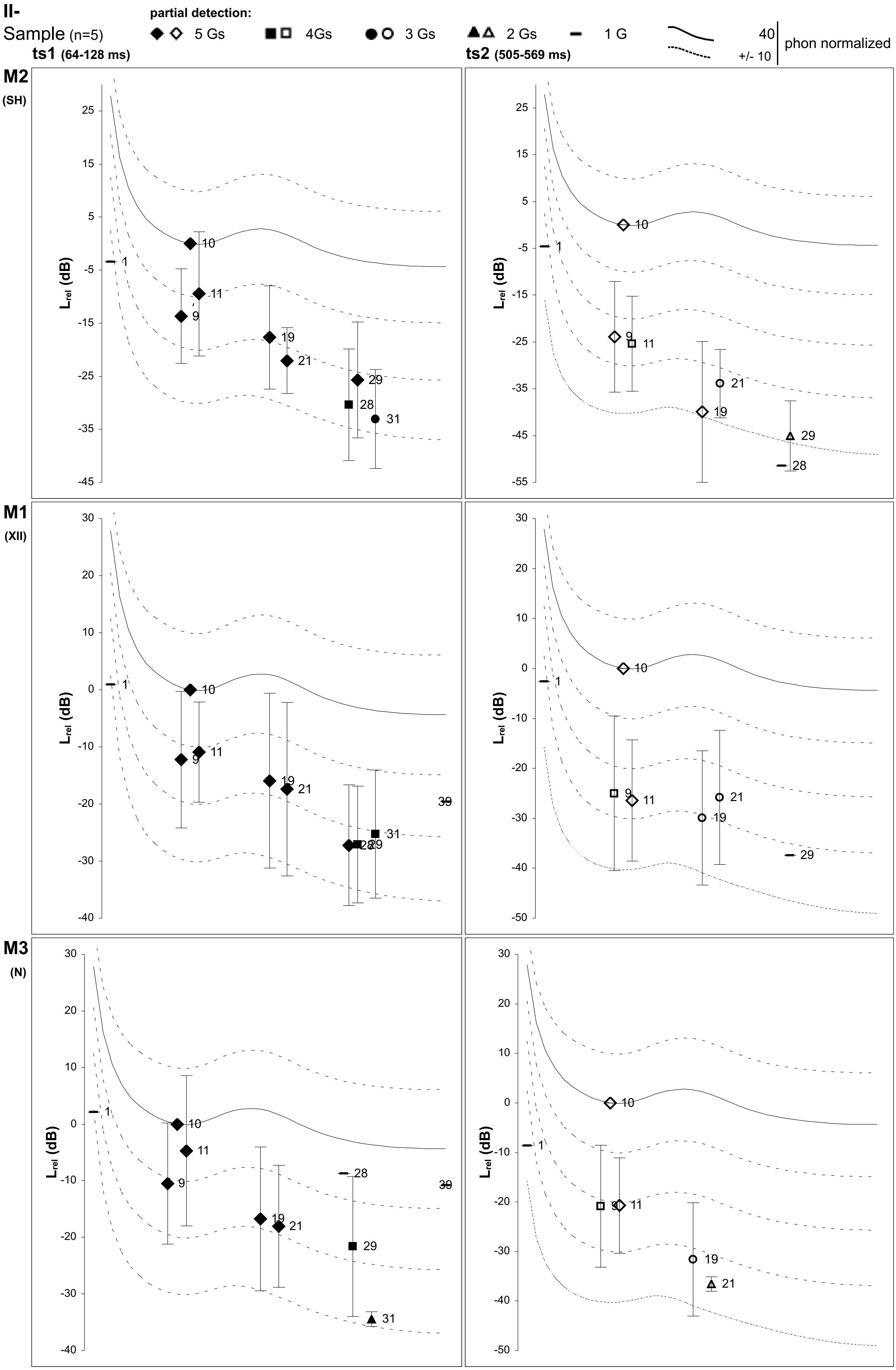


II--

M3 (Neck)

ts1 (64-128 ms) ts2 (505-569 ms)




II-
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_rel (dB)

II-
M1 (XII)

40 | phon normalized
+/- 10

ts1 (64-128 ms) **ts2** (505-569 ms)

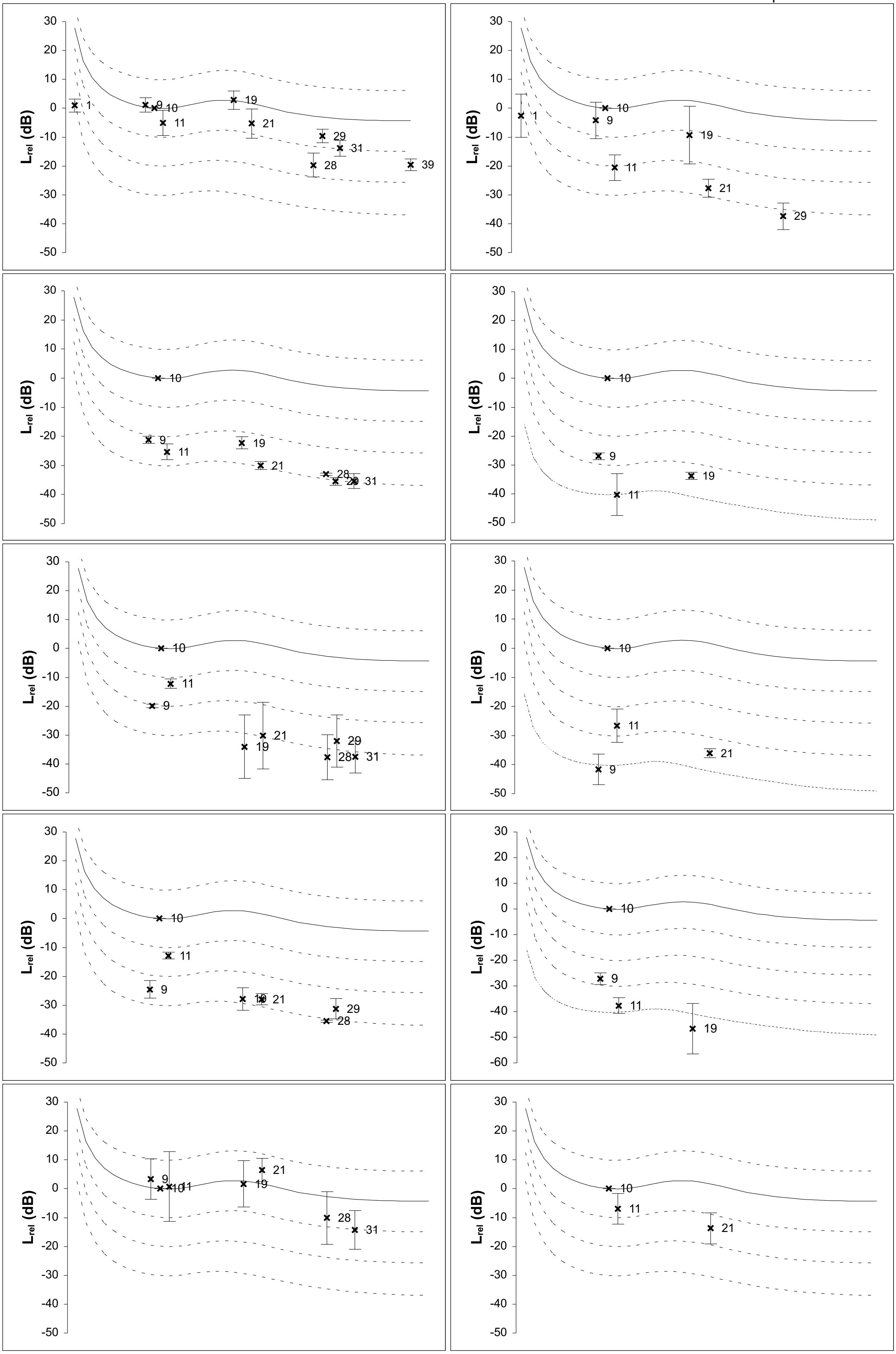
G1

G2

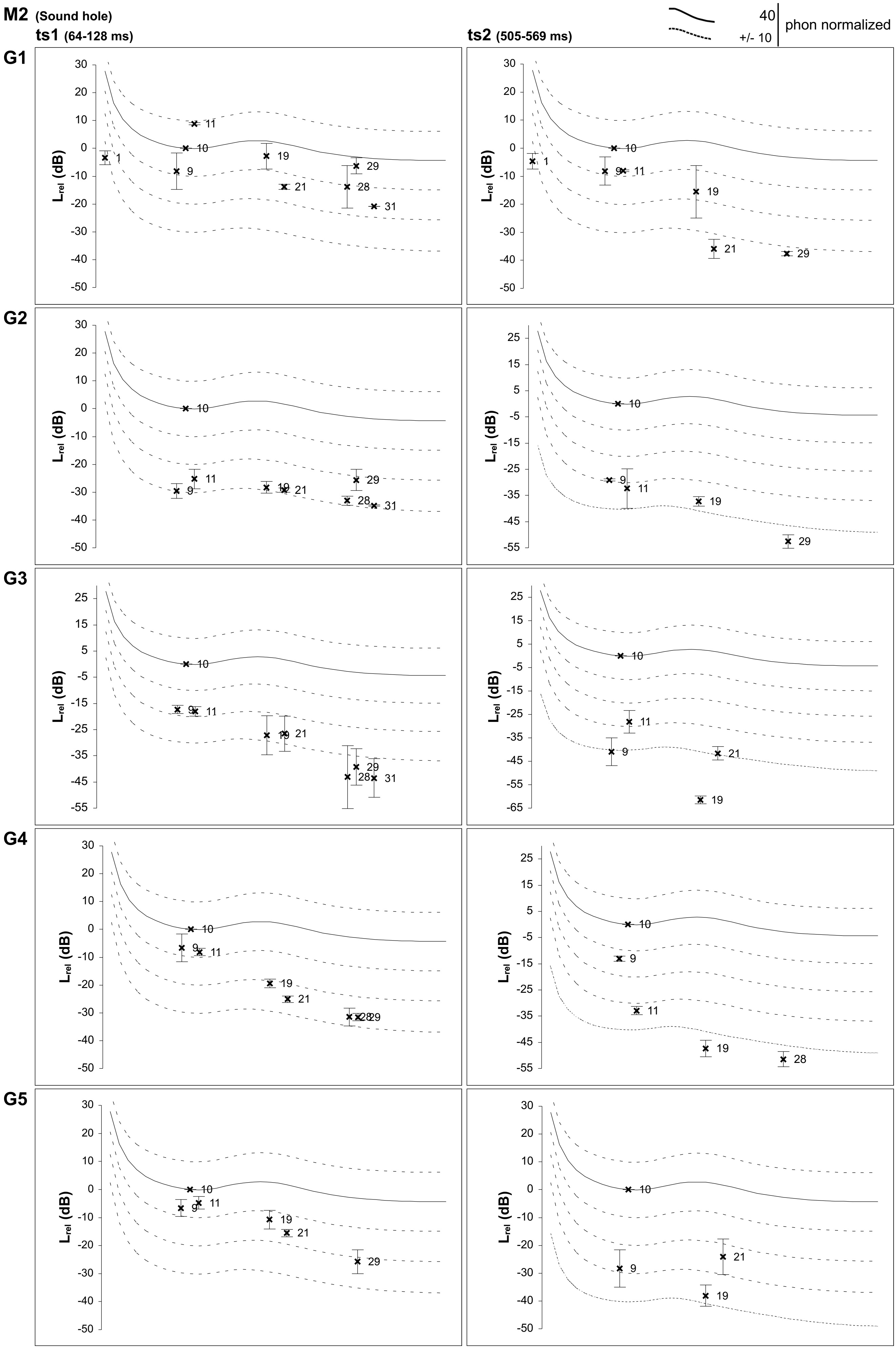
G3

G4

G5



II-
M2 (Sound hole)

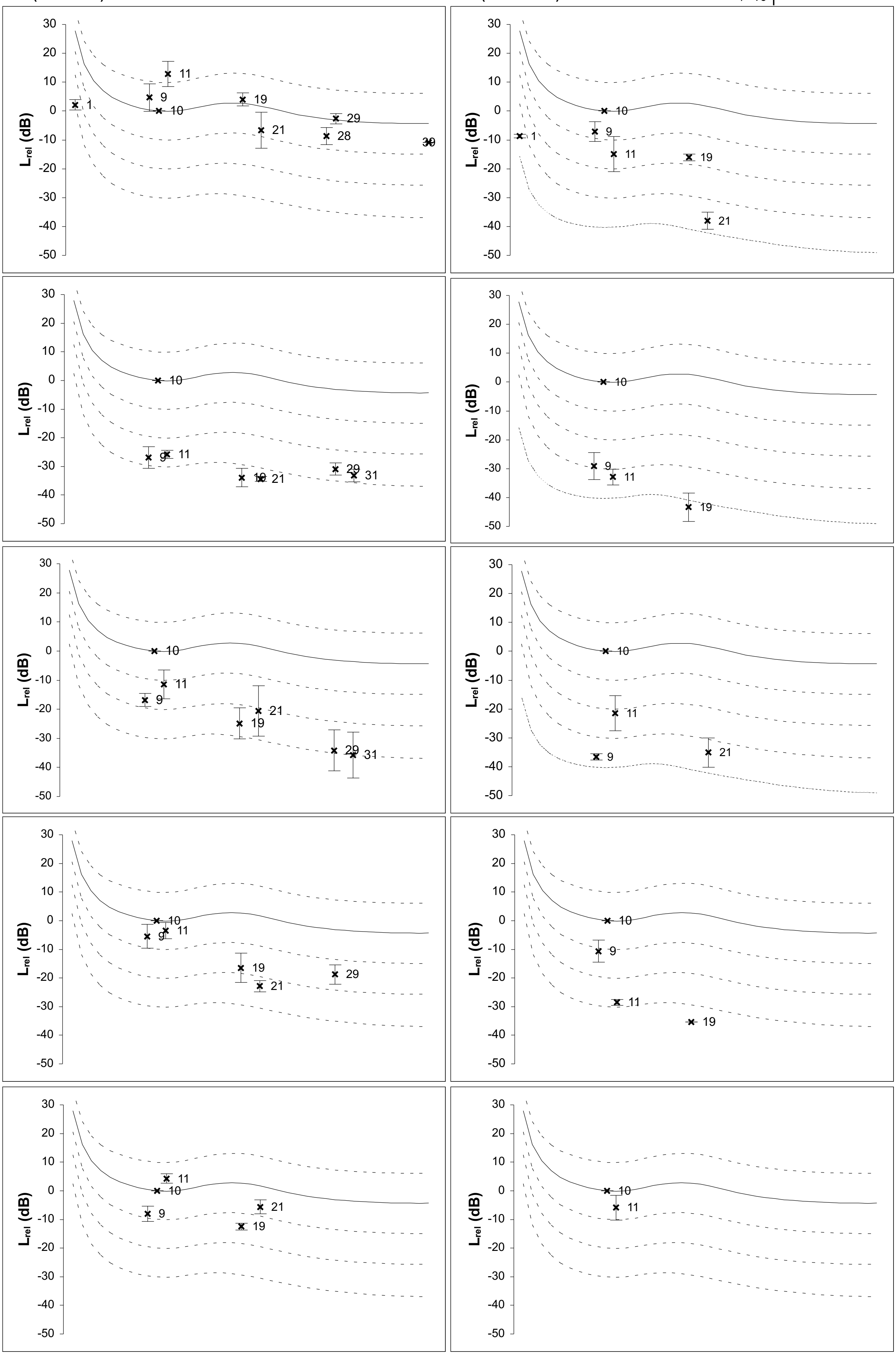


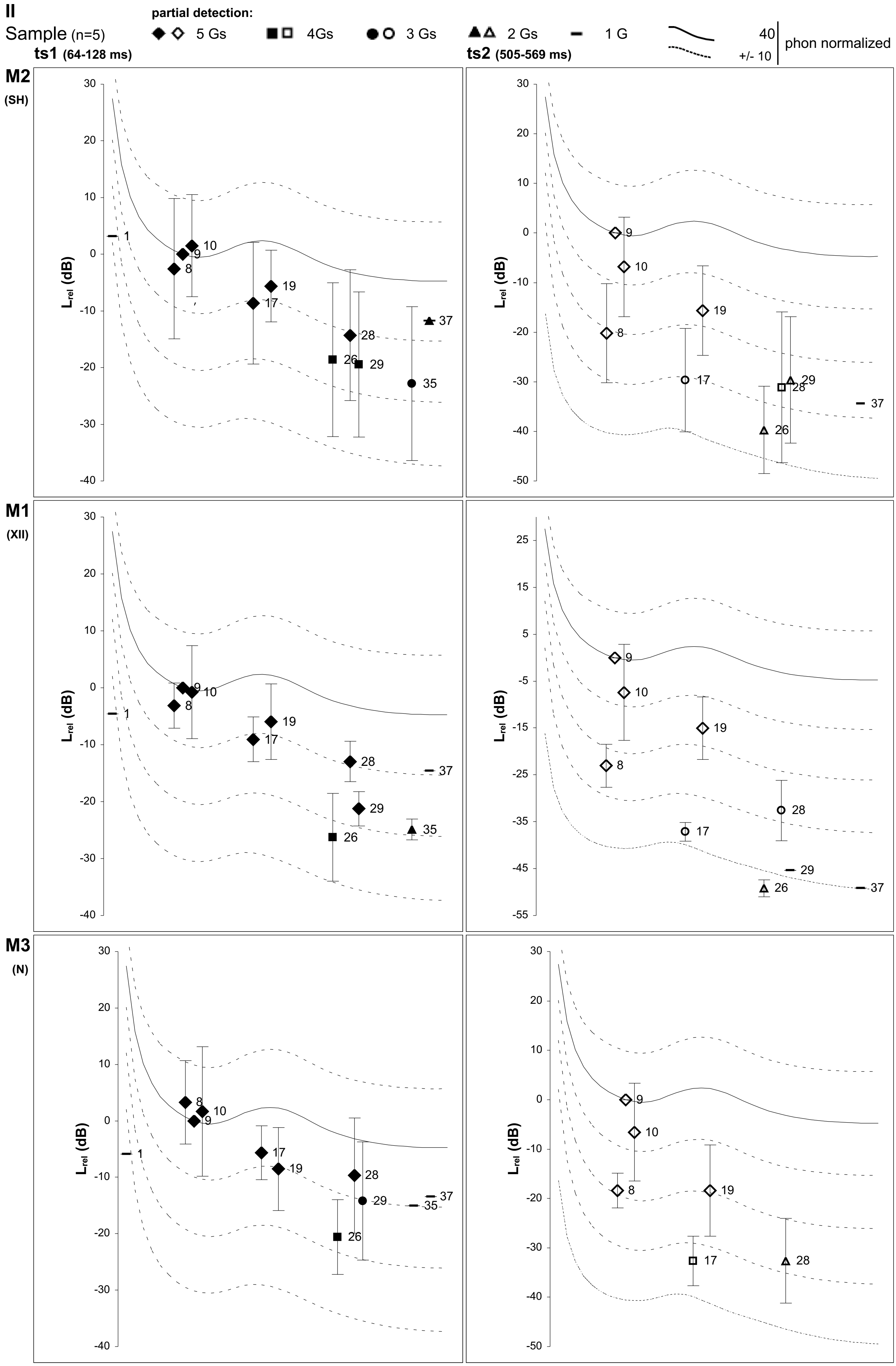
II-
M3 **(Neck)**

ts1 **(64-128 ms)** **ts2** **(505-569 ms)**

40 phon normalized
+/- 10

G1
G2
G3
G4
G5

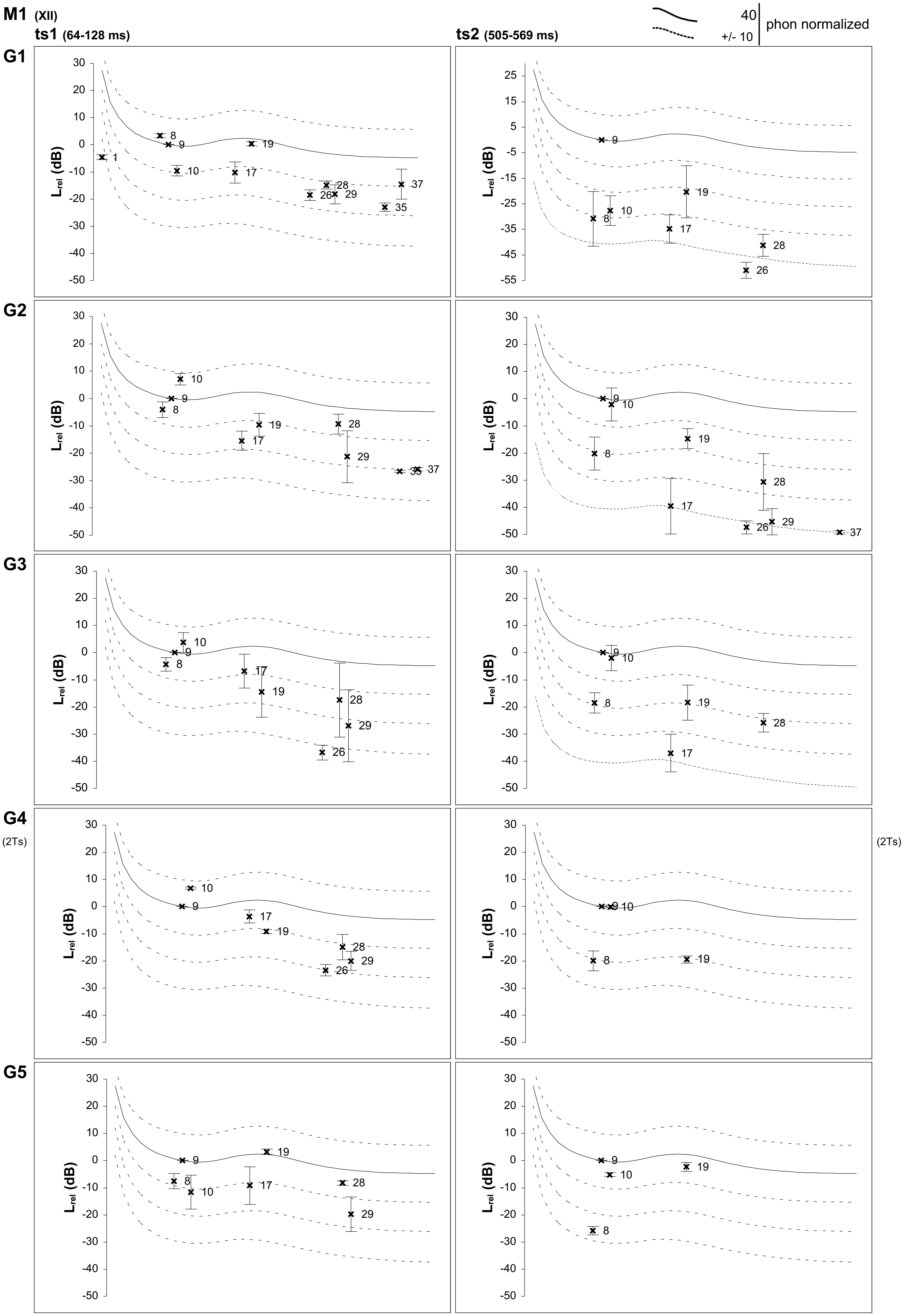



II
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_rel (dB)

II

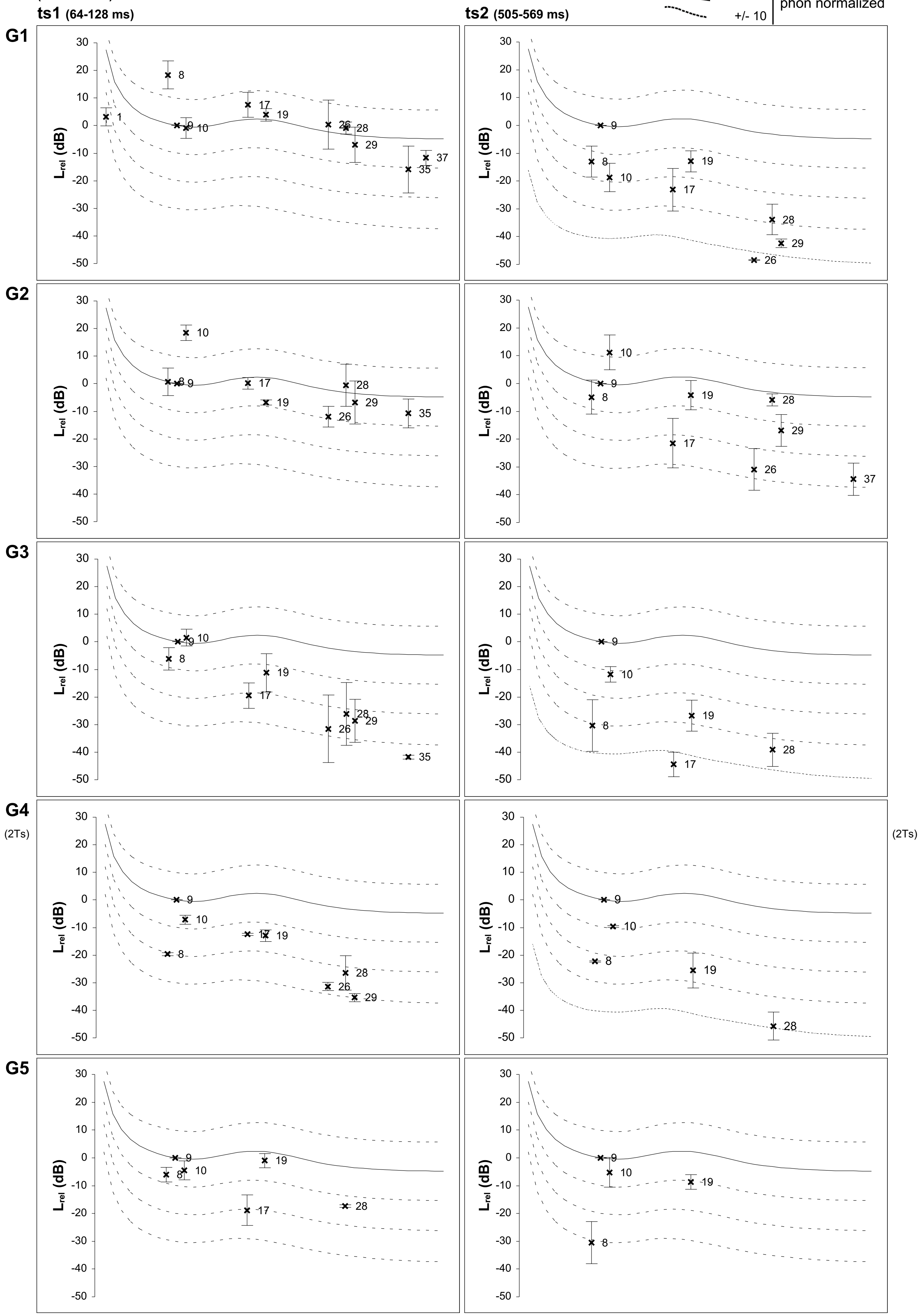
M1 (XII)

ts1 (64-128 ms) **ts2** (505-569 ms)



II

M2 **(Sound hole)**



II

M3 (Neck)

ts1 (64-128 ms) **ts2** (505-569 ms)

40 | phon normalized
+/- 10 |

G1

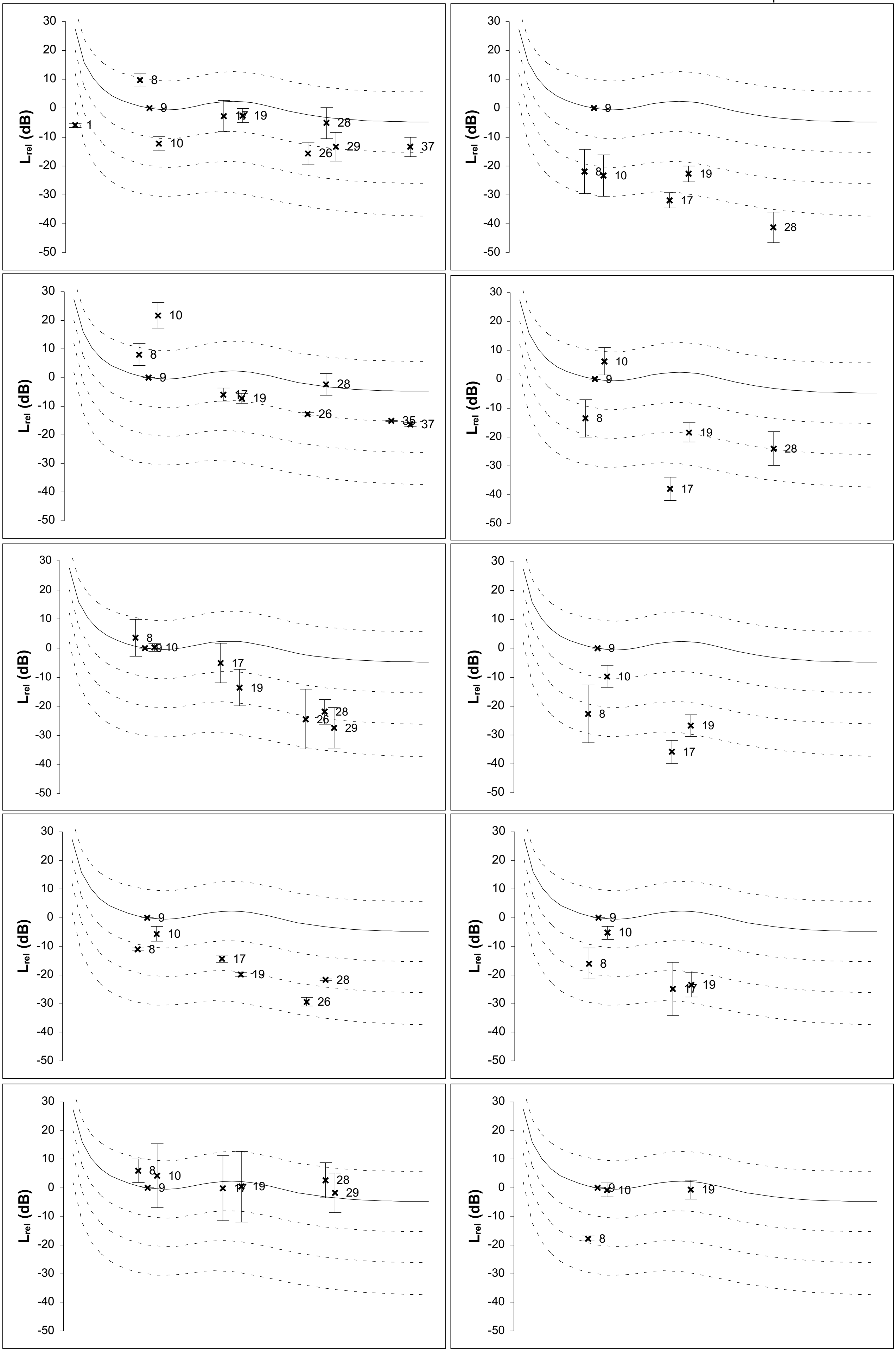
G2

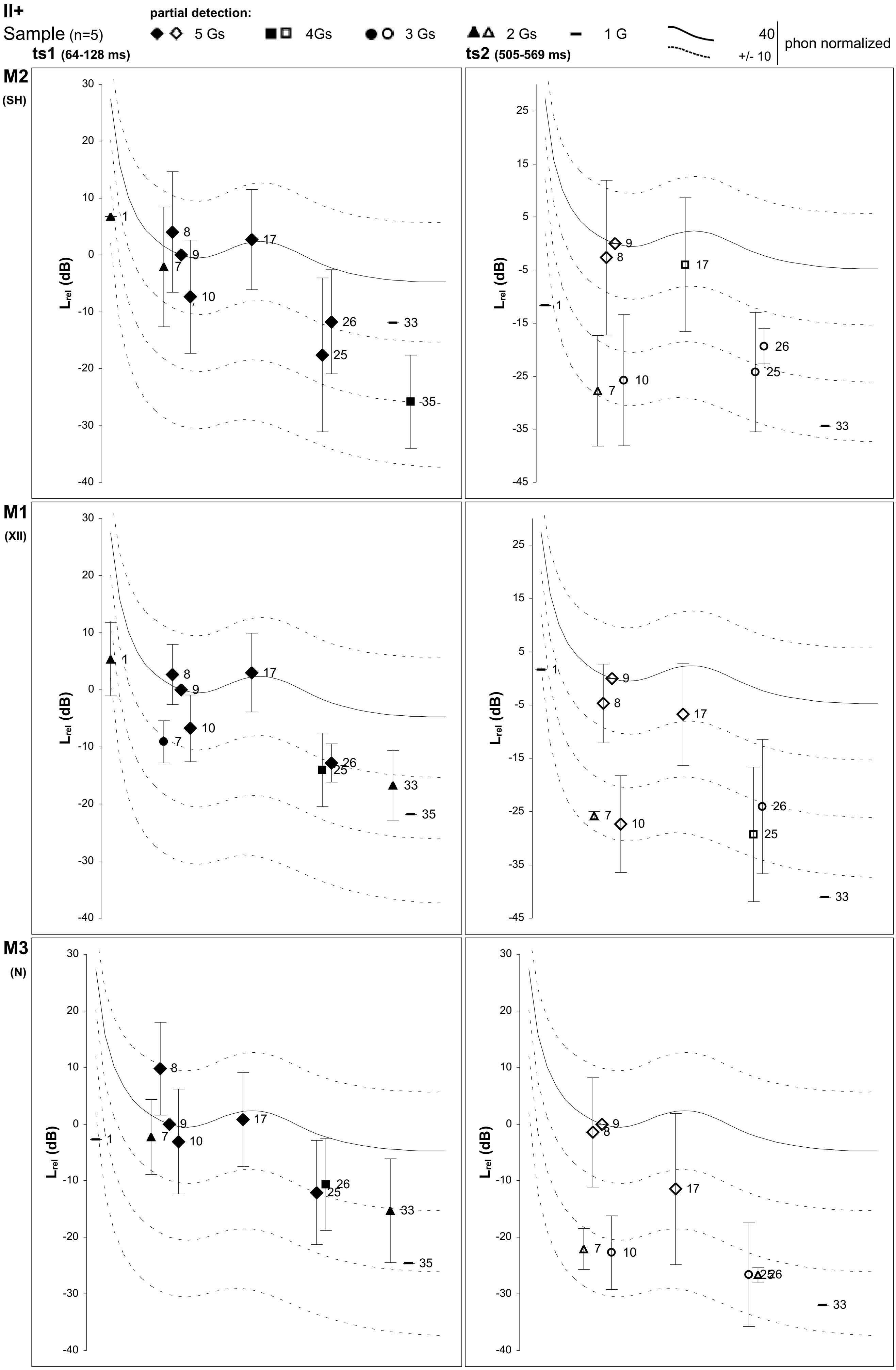
G3

G4

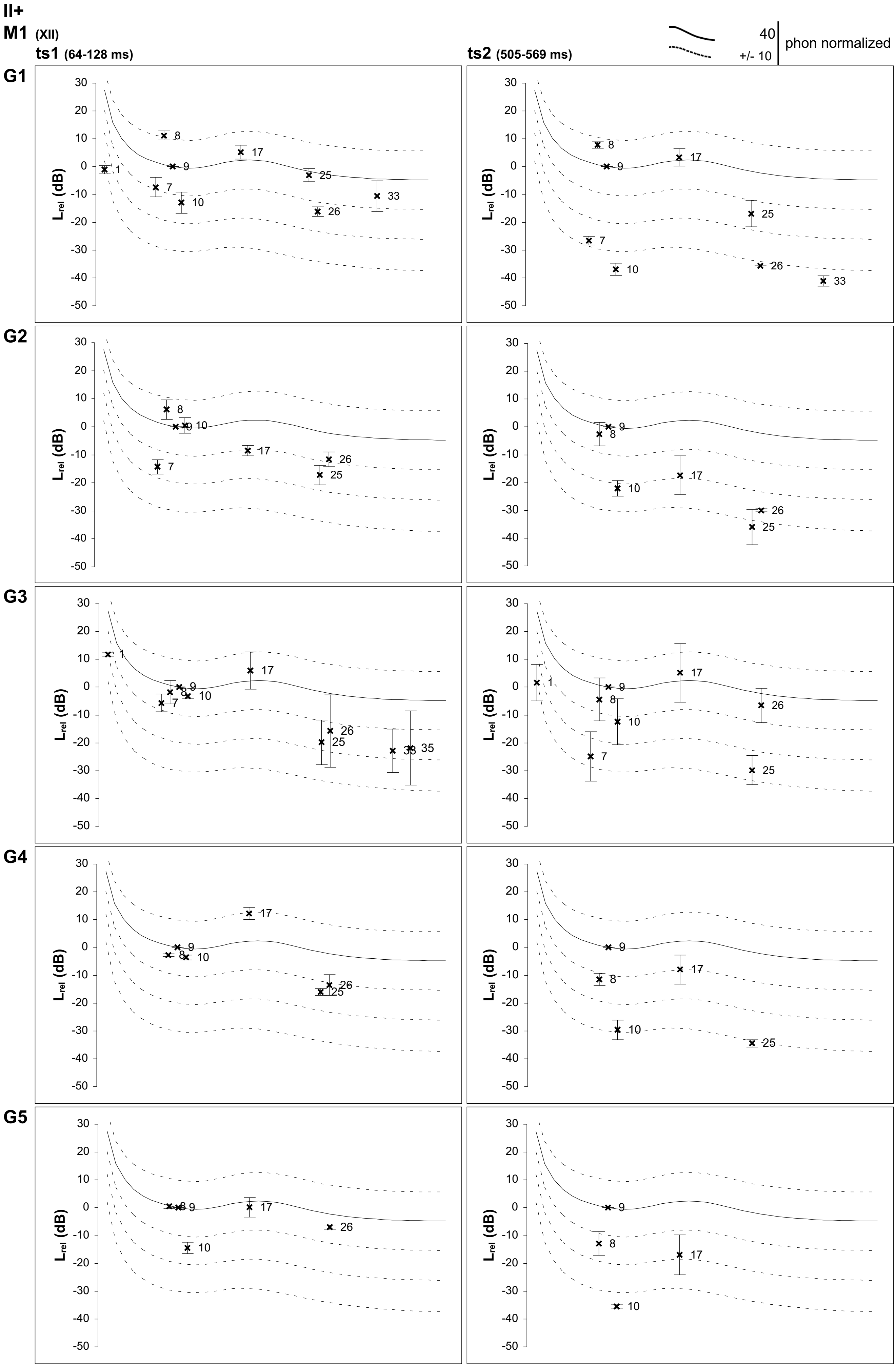
(2Ts)

G5





II+
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_rel (dB)


II+
M1 (XII)
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
L_{rel} (dB)

II+

M2 **(Sound hole)**

40 | phon normalized
+/- 10

ts1 **(64-128 ms)**

ts2 **(505-569 ms)**

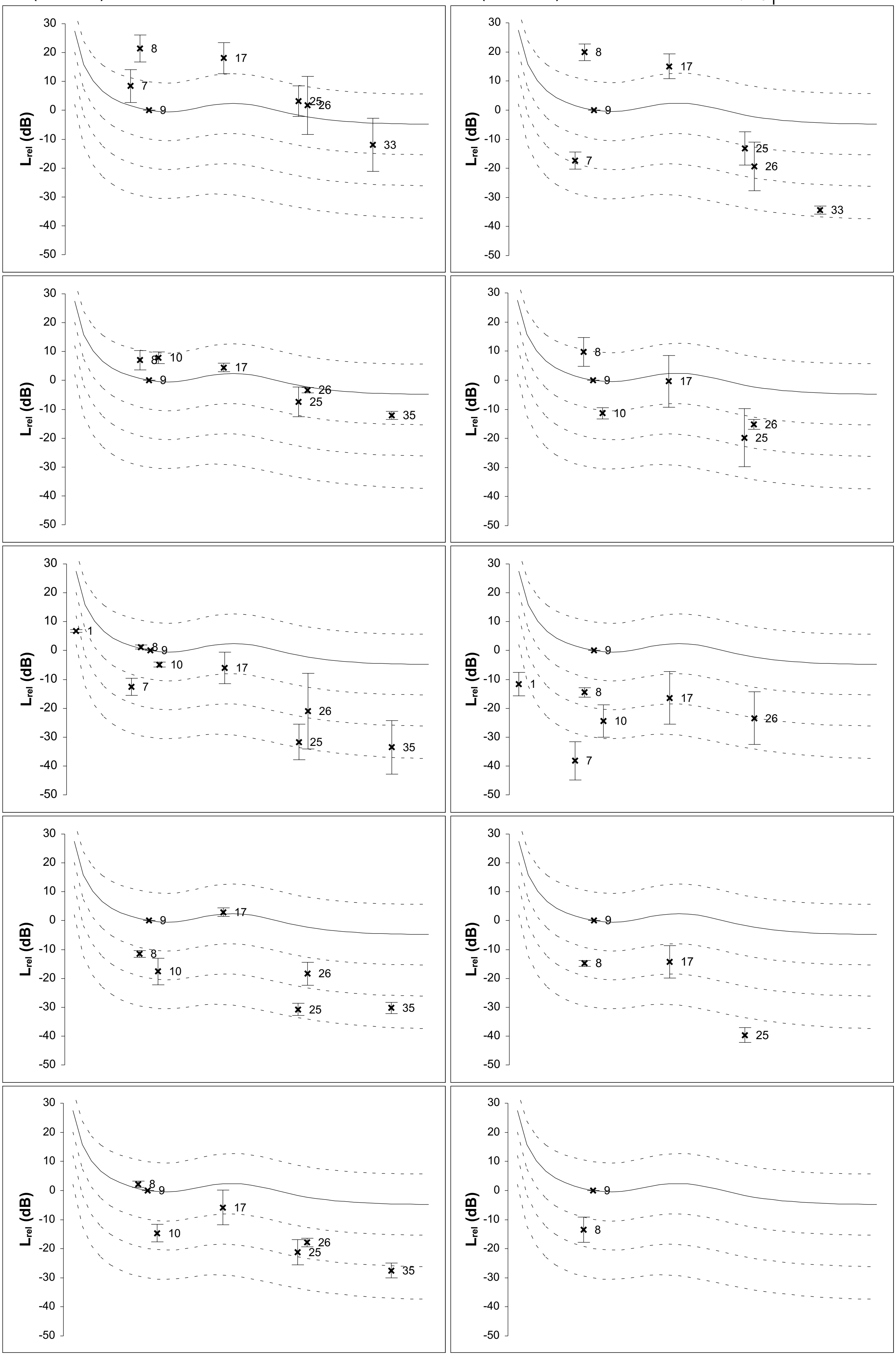
G1
(2Ts)

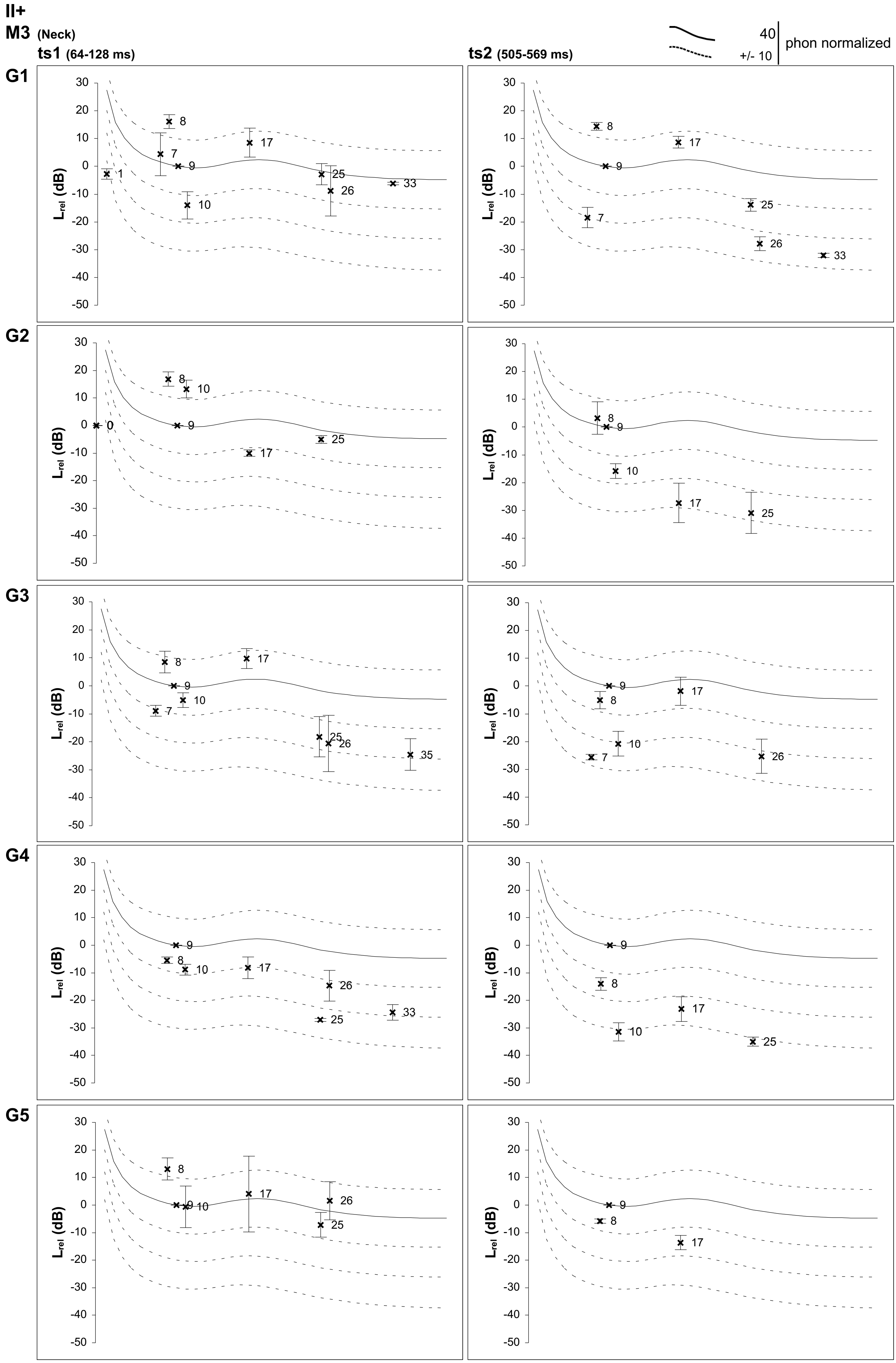
G2

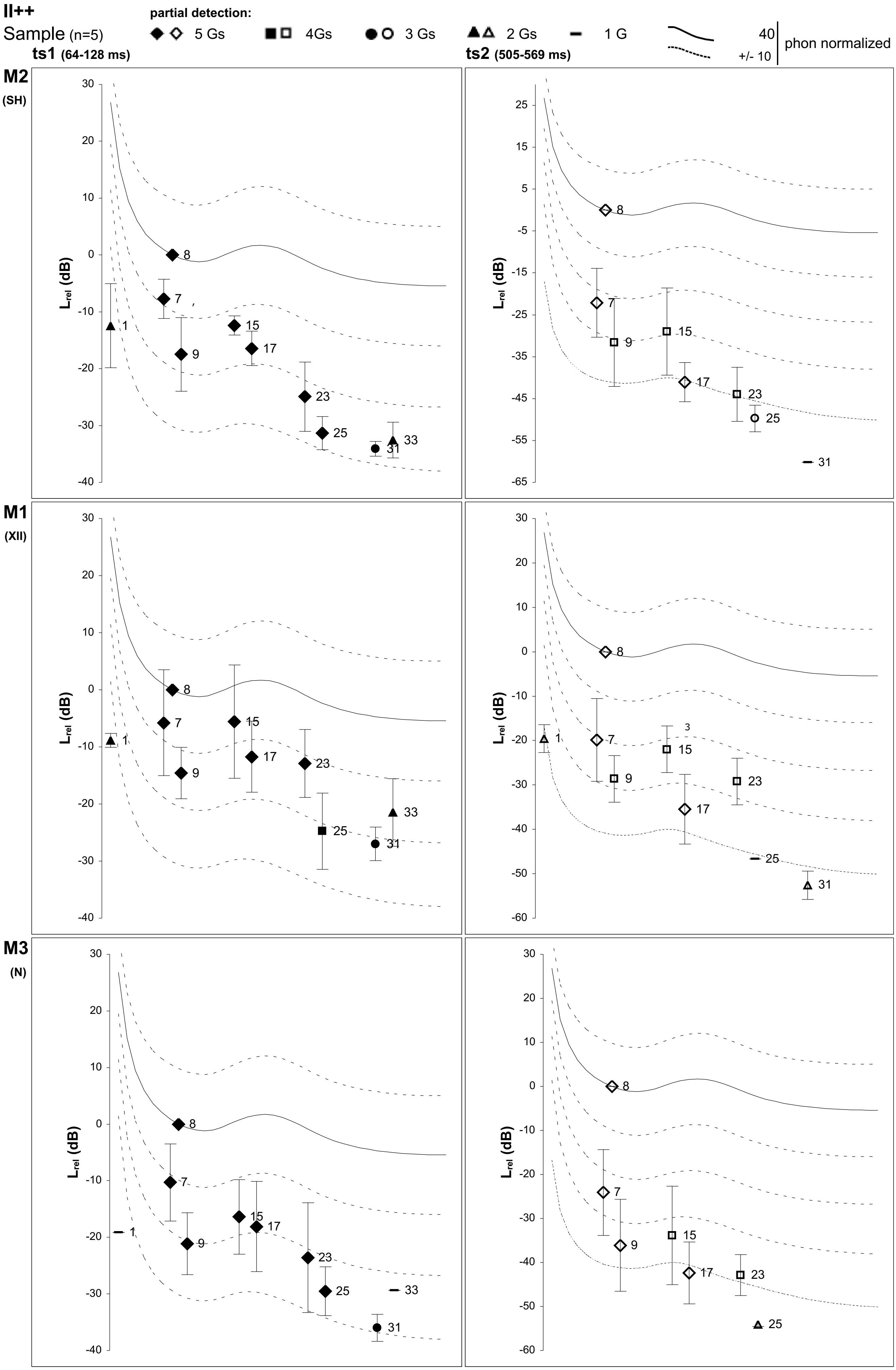
G3

G4

G5



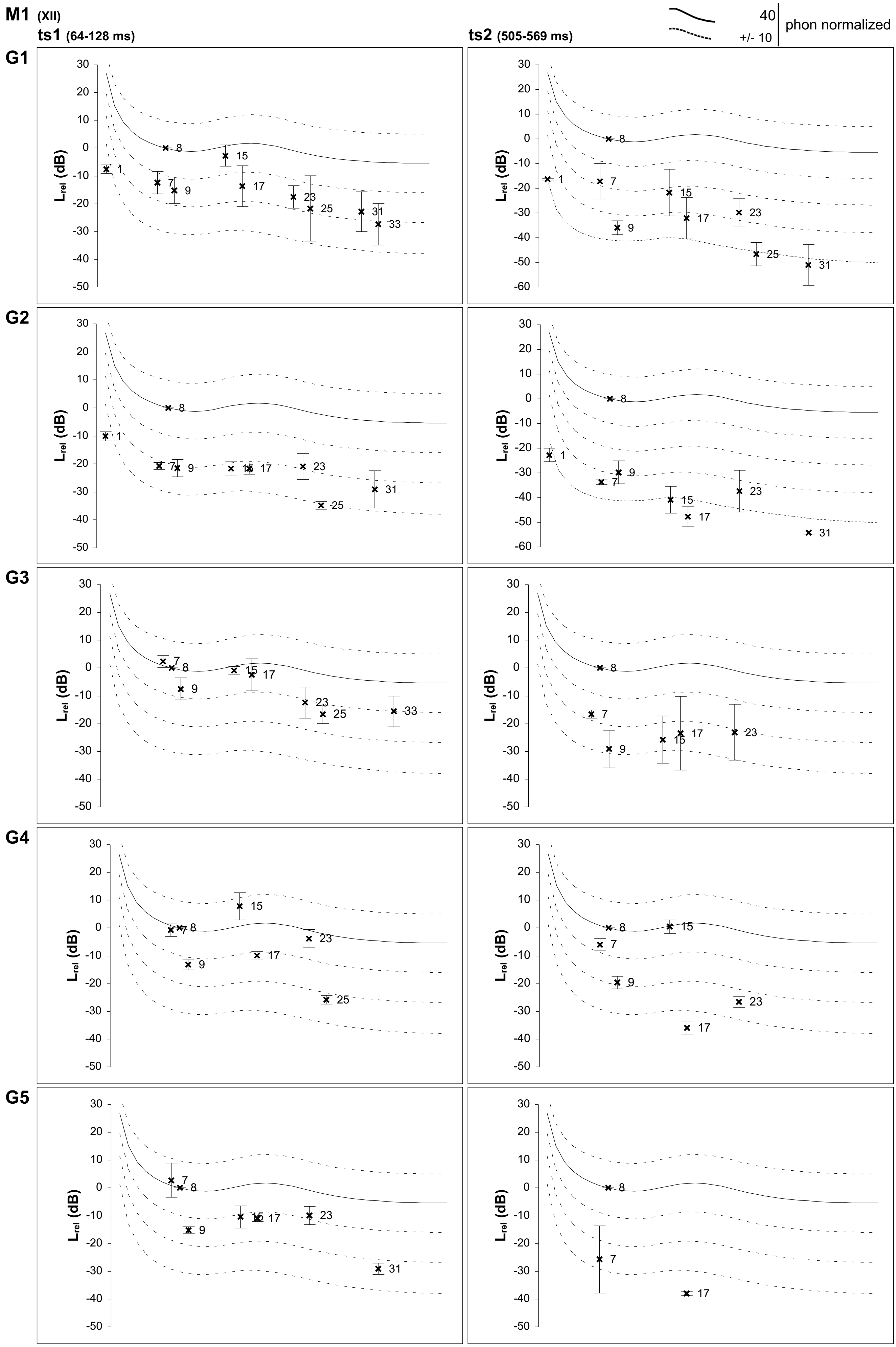

II+
M3 (Neck)
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
Lrel (dB)

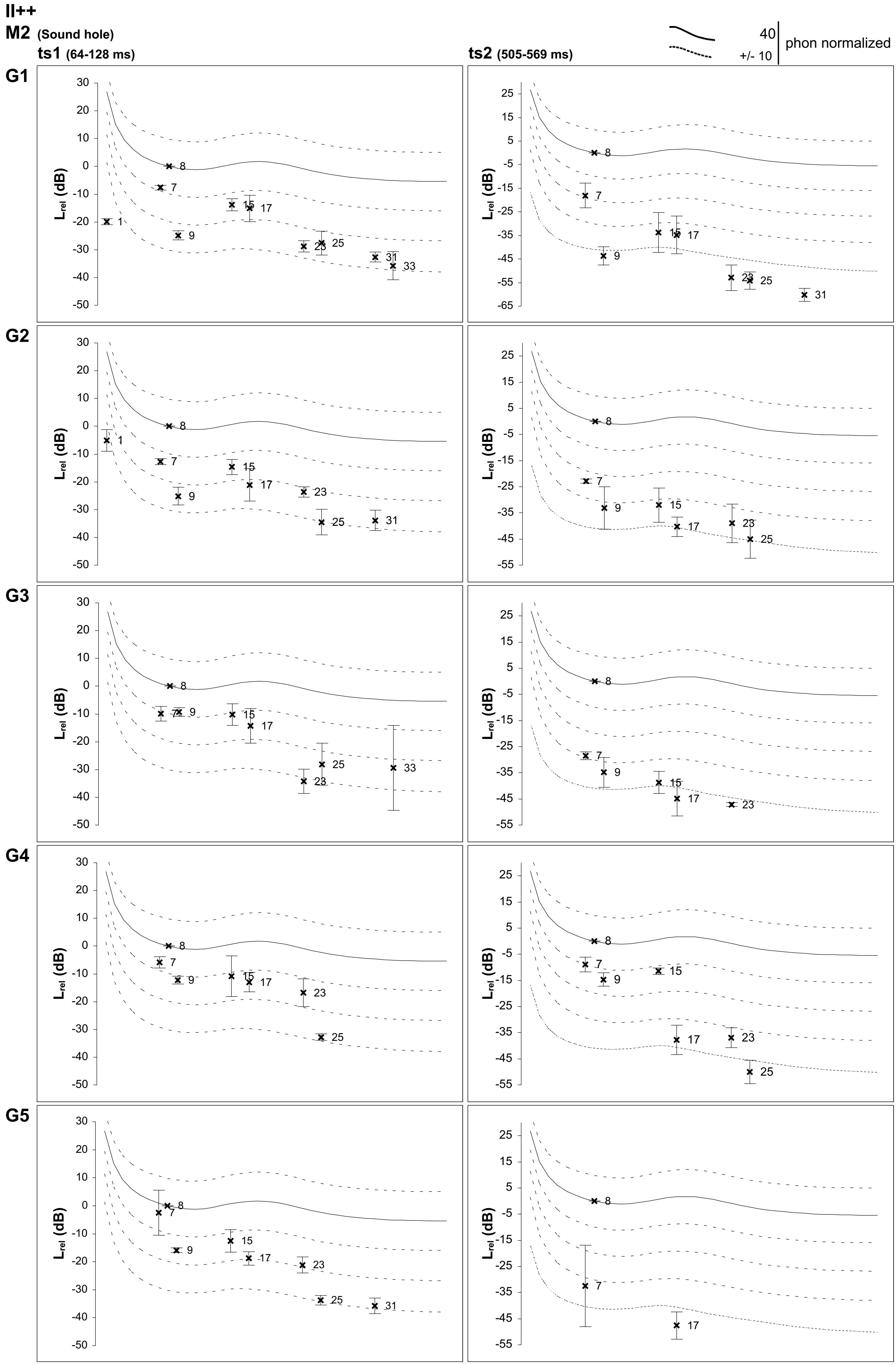


II++
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_{rel} (dB)

II++

M1 (XII)


ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
L_{rel} (dB)


II++
M2 (Sound hole)
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
Lrel (dB)

II++

M3 **(Neck)**

ts1 **(64-128 ms)** **ts2** **(505-569 ms)**

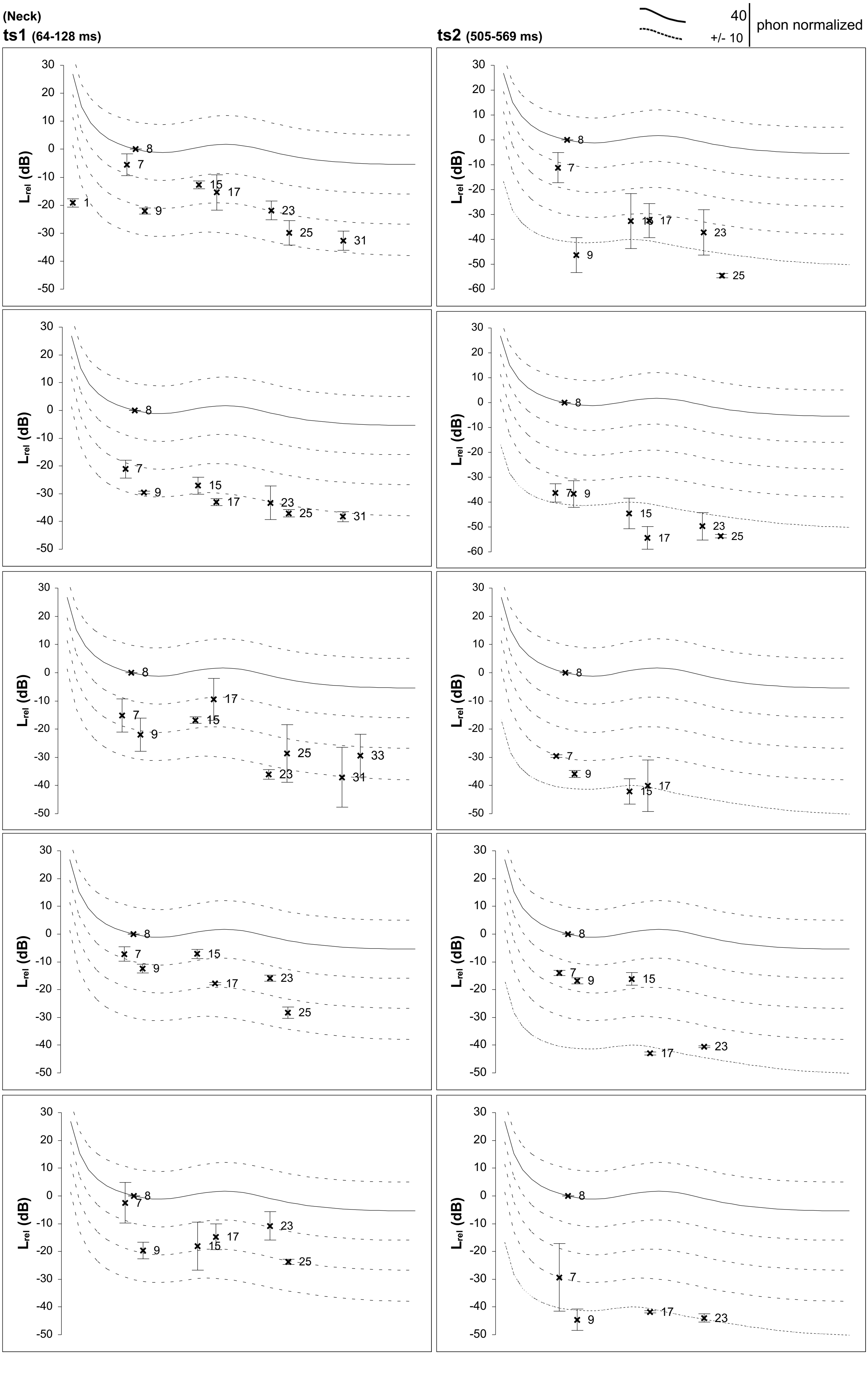
G1

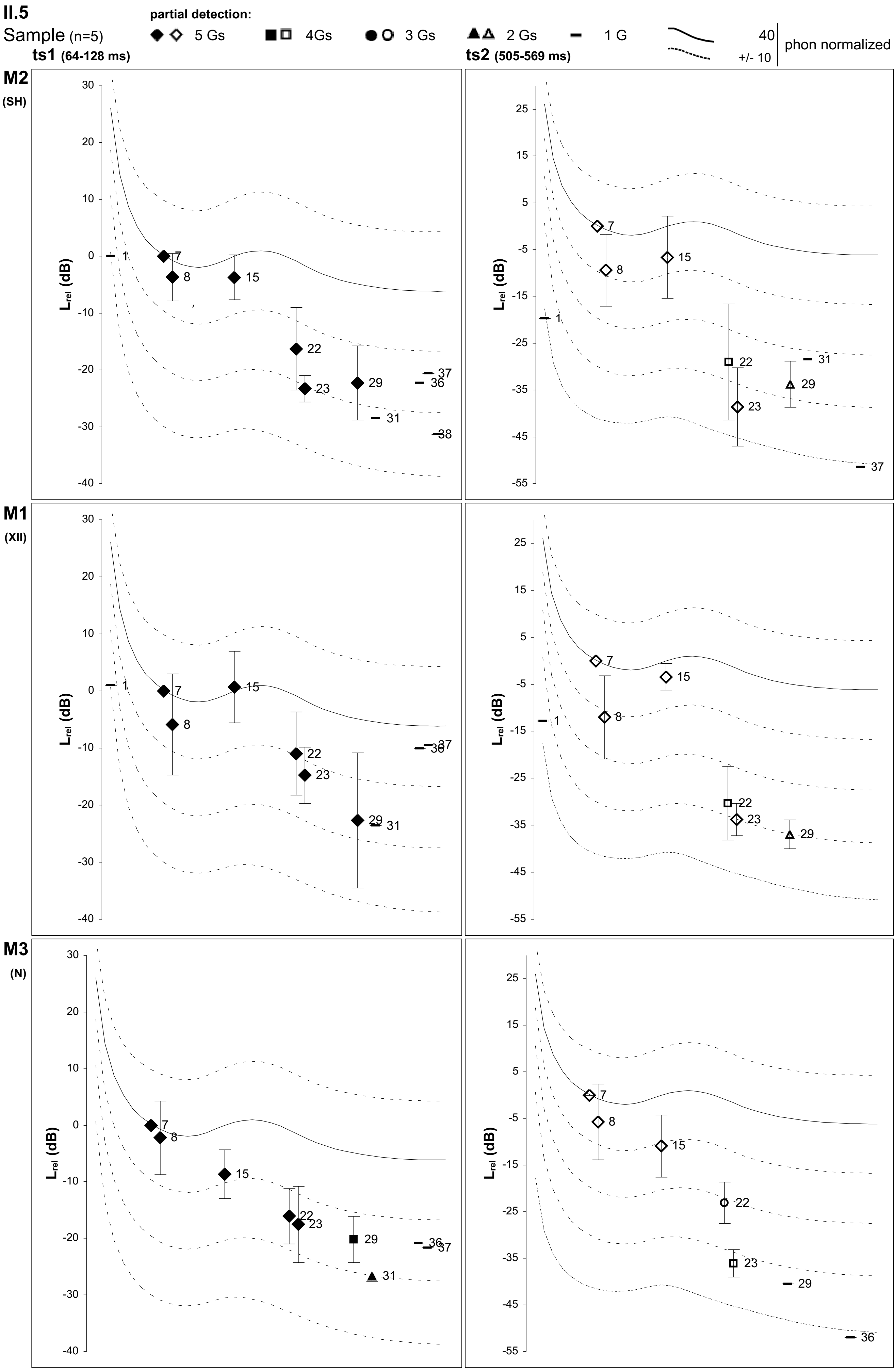
G2

G3

G4

G5




II.5
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
Lrel (dB)
30
20
10
0
-10
-20
-30
-40
25
15
5
-5
-15
-25
-35
-45
-55
1
7
8
15
22
23
29
31
36
37
38

II.5

M1 (XII)

ts1 (64-128 ms) **ts2** (505-569 ms)

40 / +/- 10 phon normalized

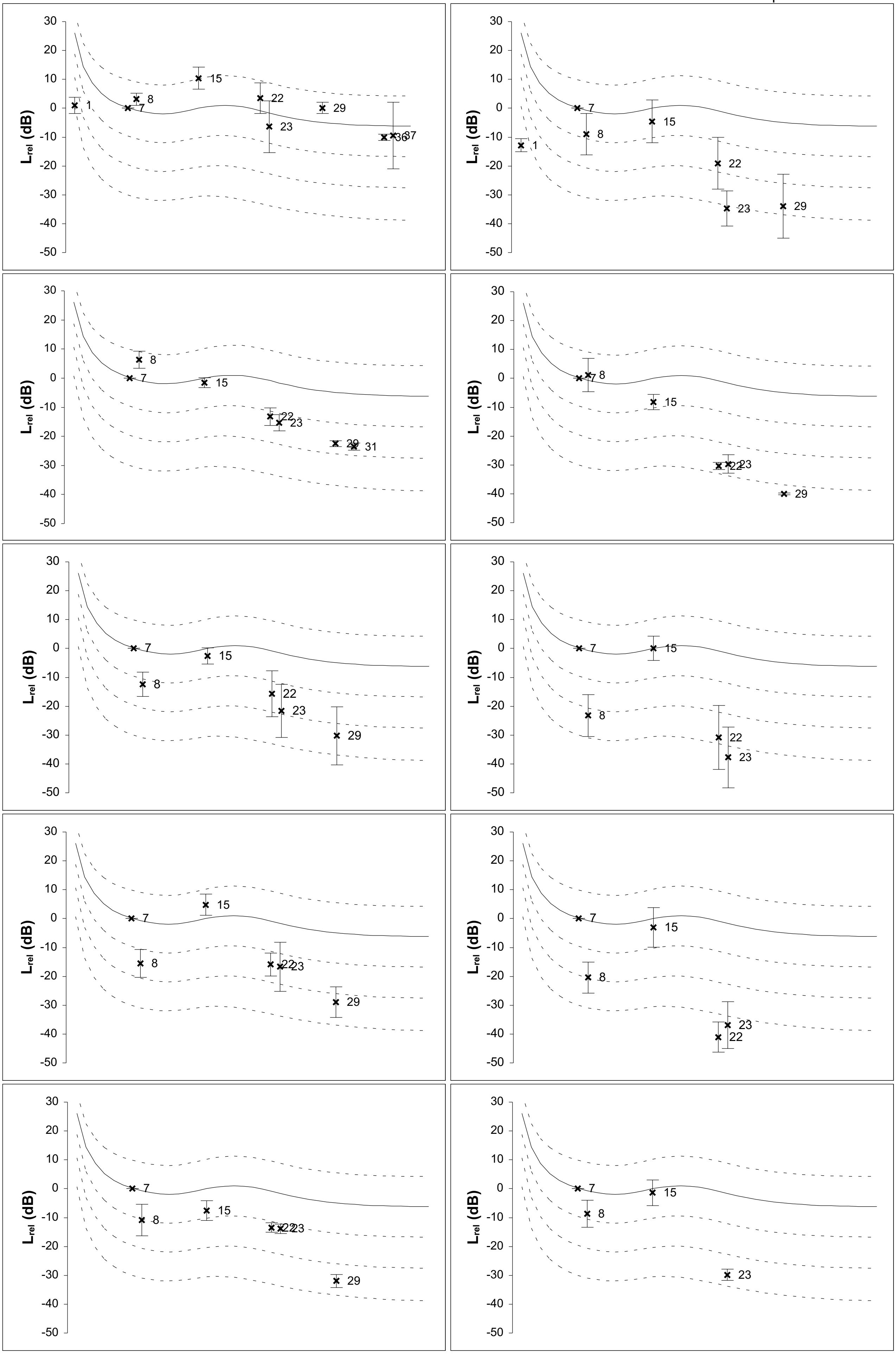
G1

G2

G3

G4

G5

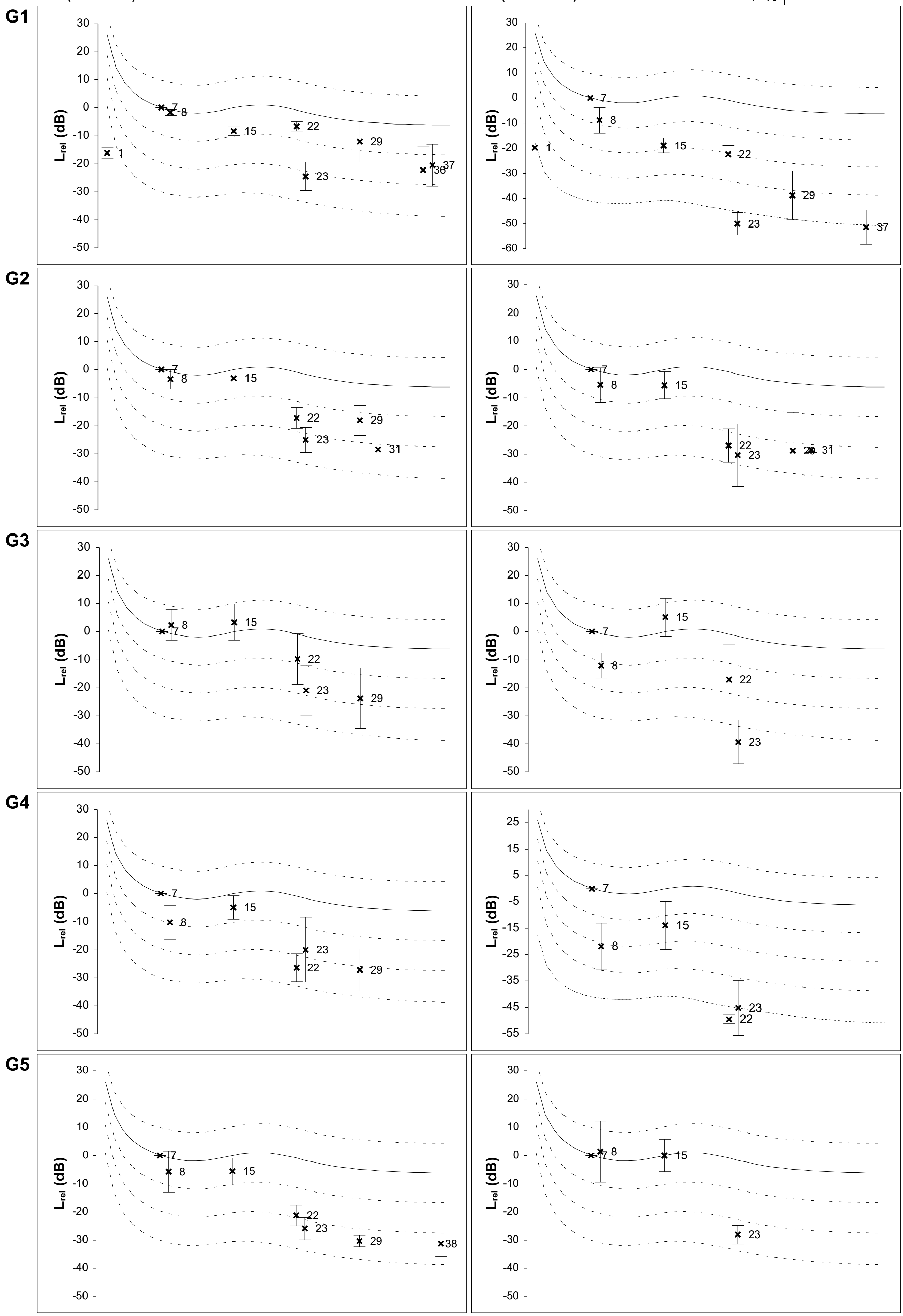


II.5

M2 (Sound hole)

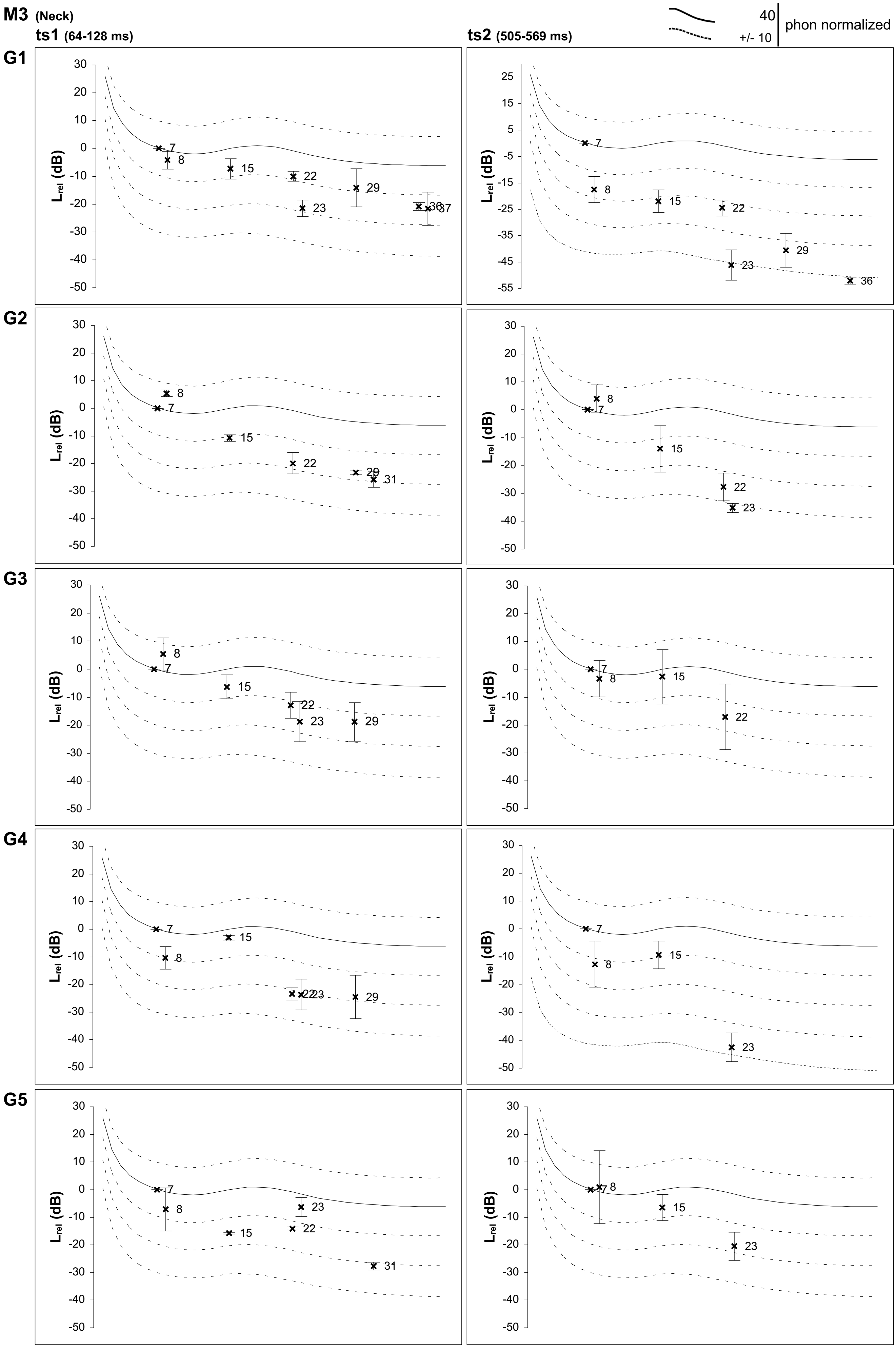
ts1 (64-128 ms) **ts2** (505-569 ms)

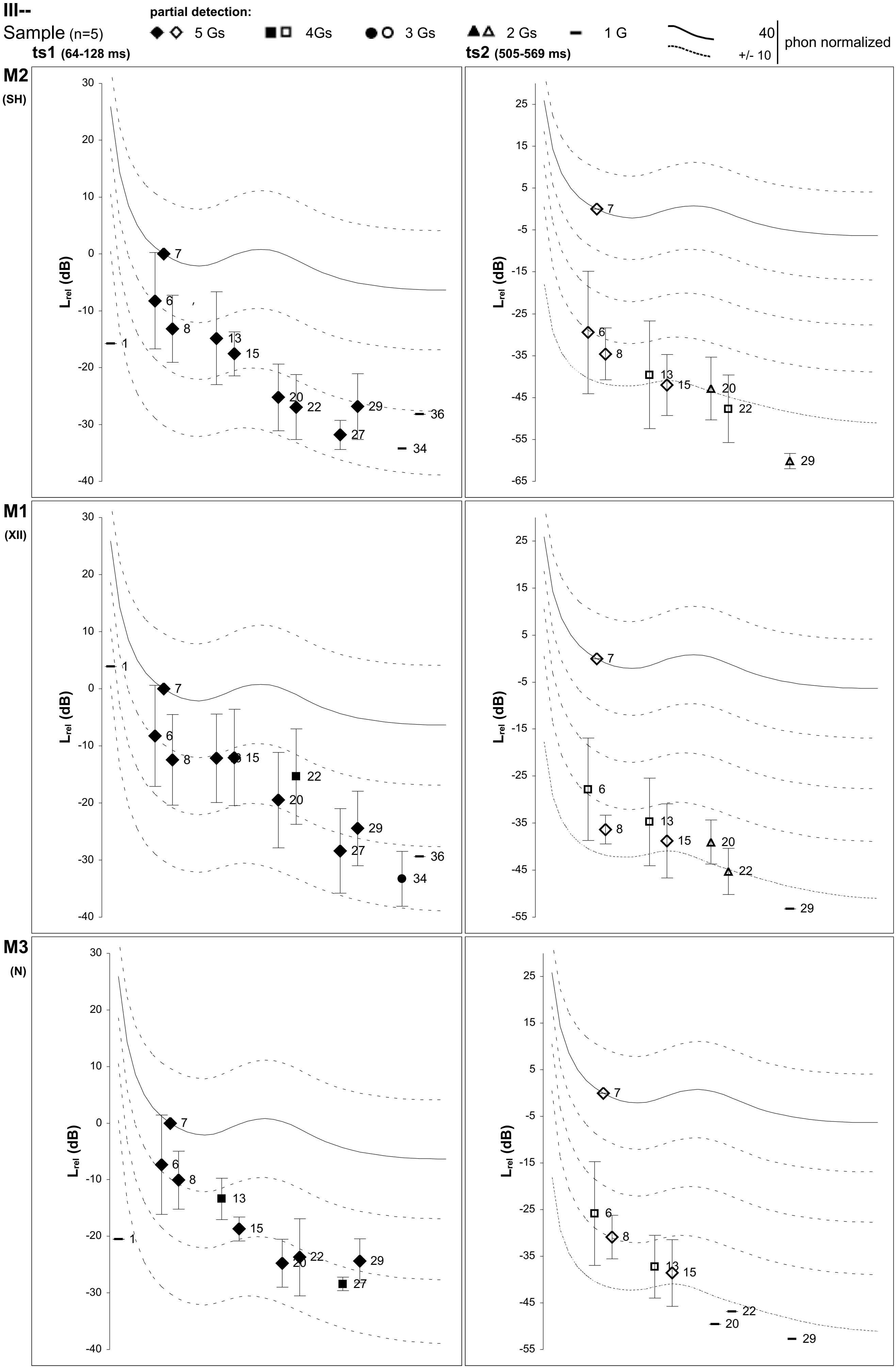
40 / +/- 10 | phon normalized



II.5

M3 **(Neck)**


40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
G1
G2
G3
G4
G5
L_rel (dB)


III--
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_rel (dB)

III--

M1 (XII)

ts1 (64-128 ms) **ts2** (505-569 ms)

40 / +/- 10 phon normalized

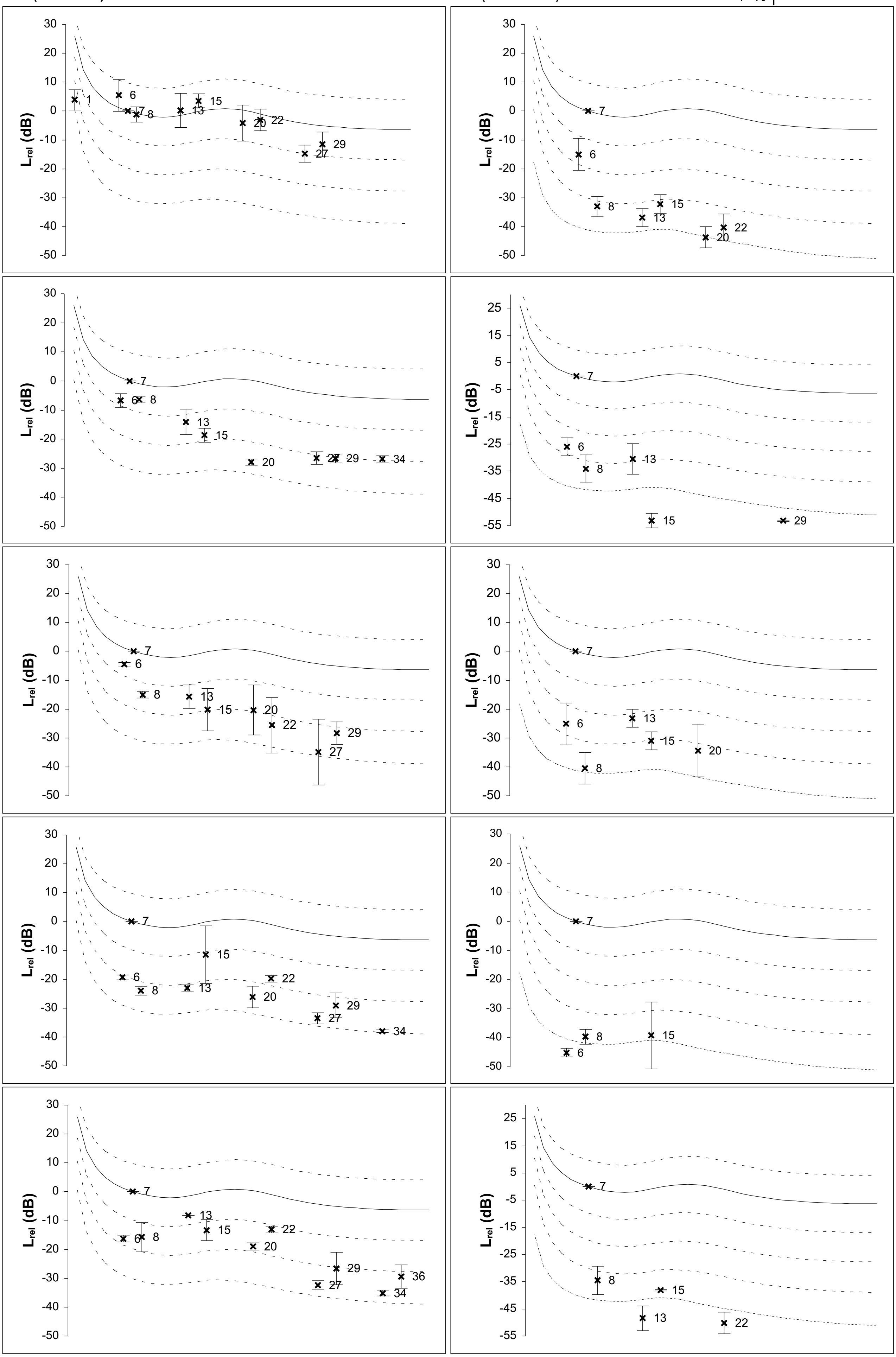
G1

G2

G3

G4

G5



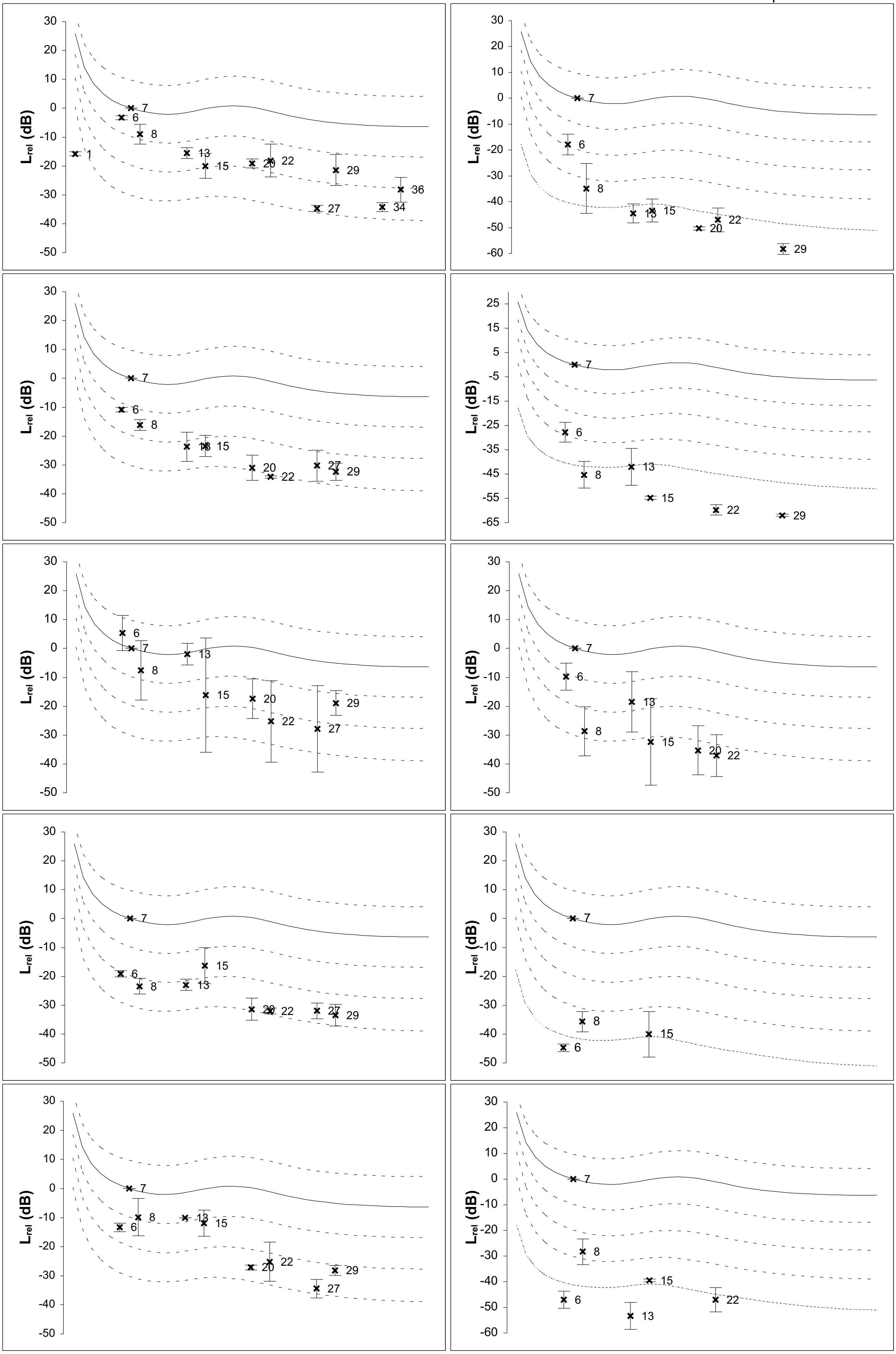
III--

M2 **(Sound hole)**

ts1 **(64-128 ms)** | **ts2** **(505-569 ms)**

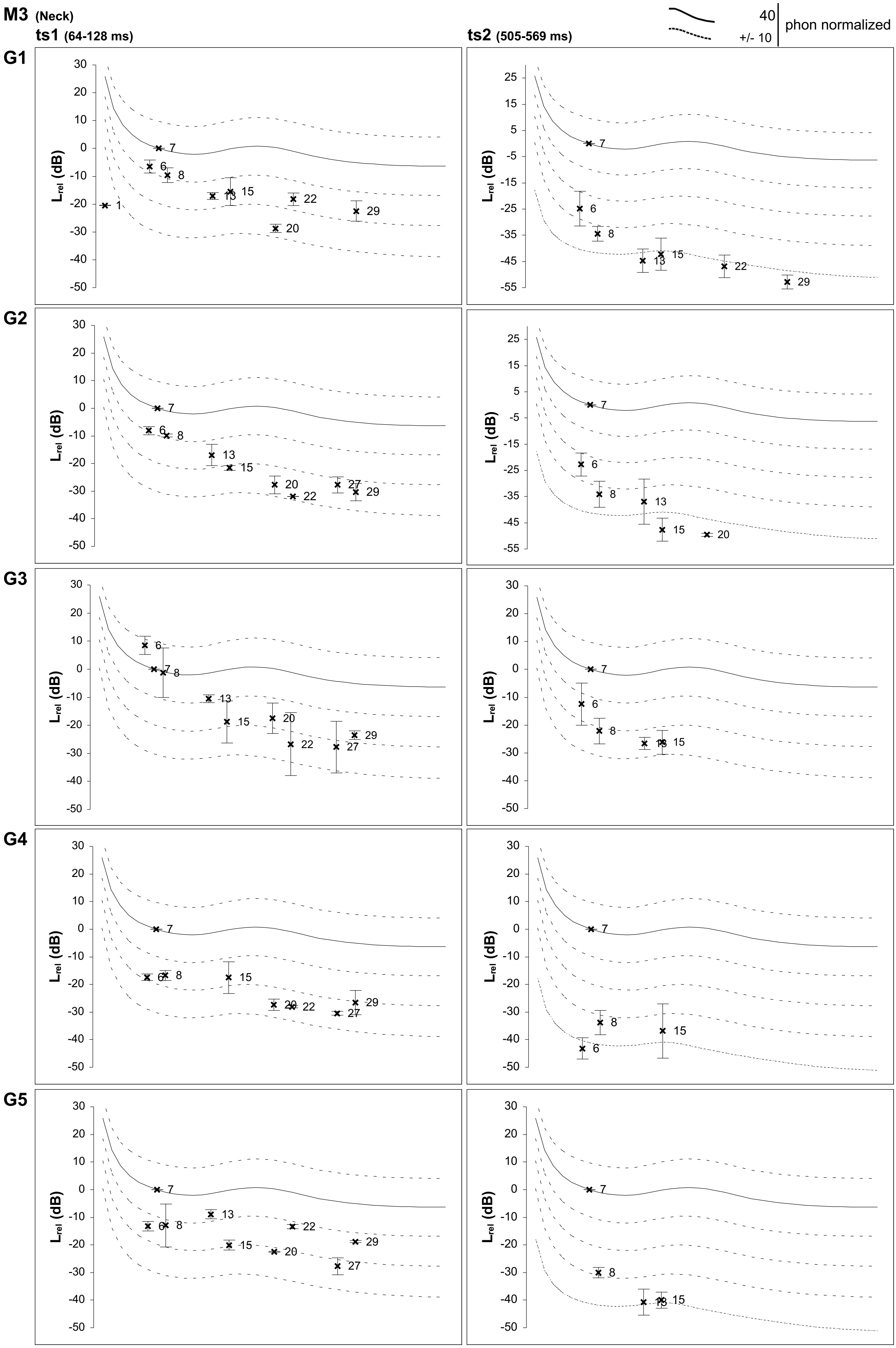
40 / +/- 10 | phon normalized

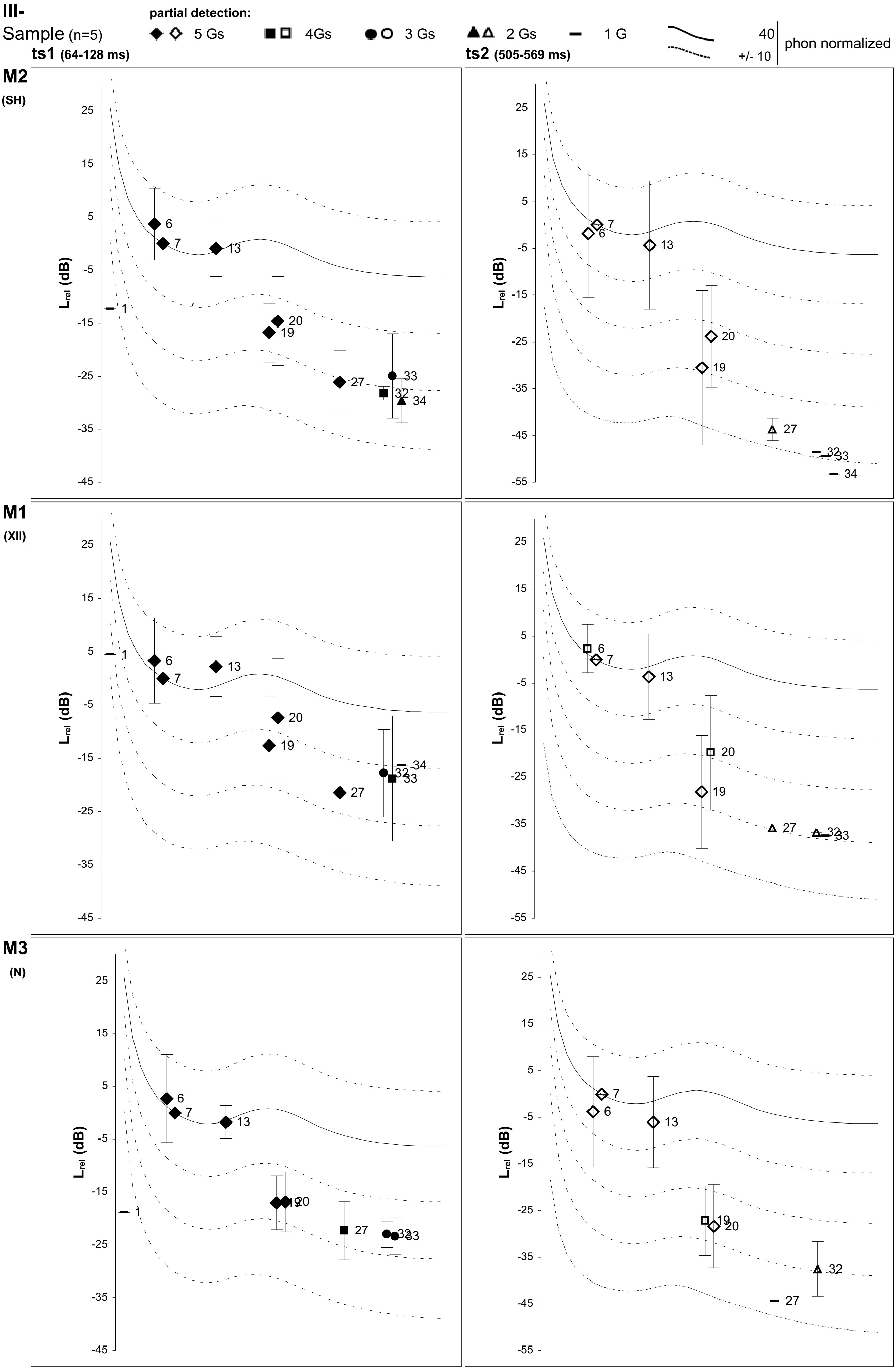
G1
G2
G3
G4
G5



III--

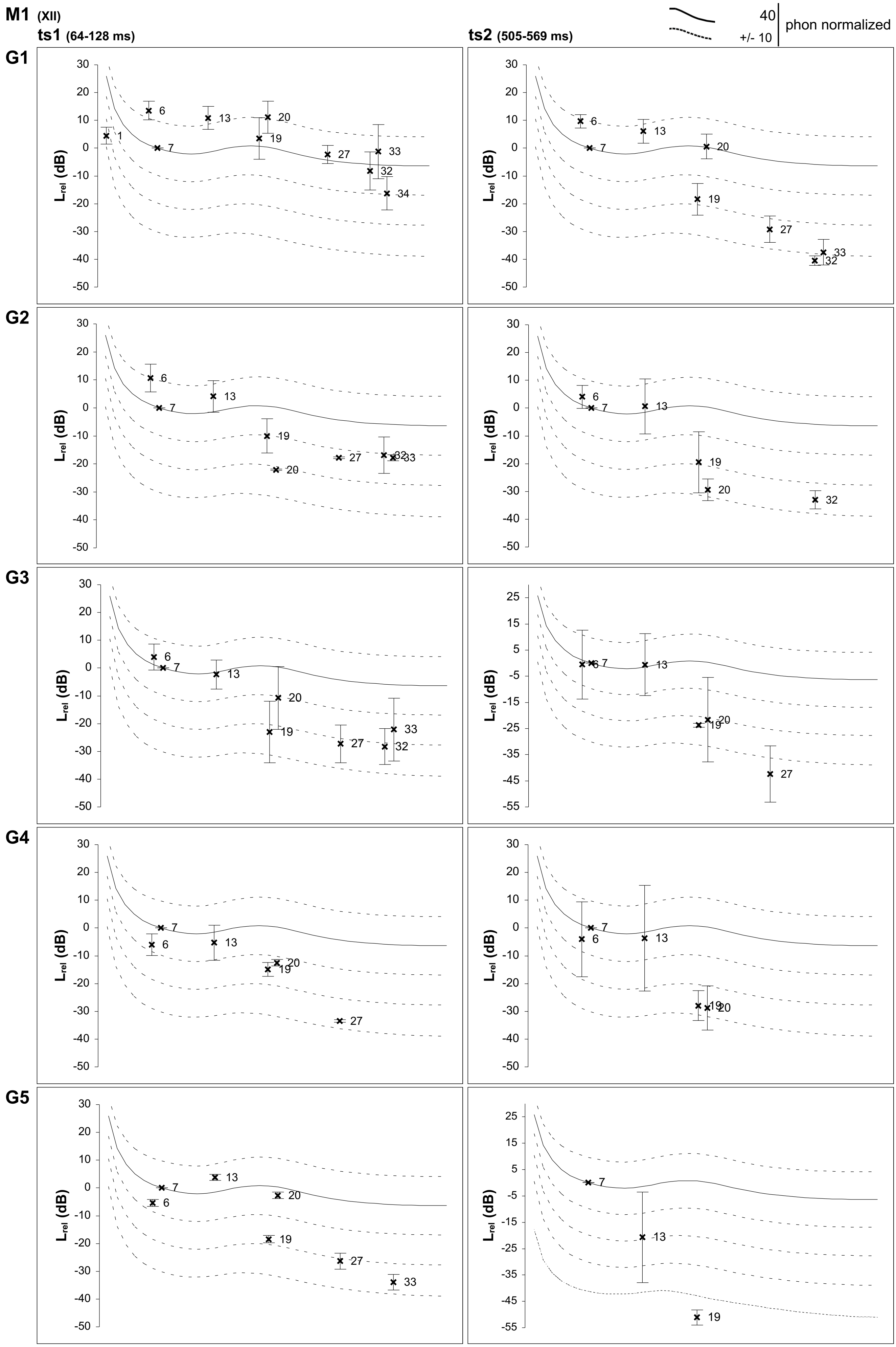
M3 (Neck)


ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
L_{rel} (dB)

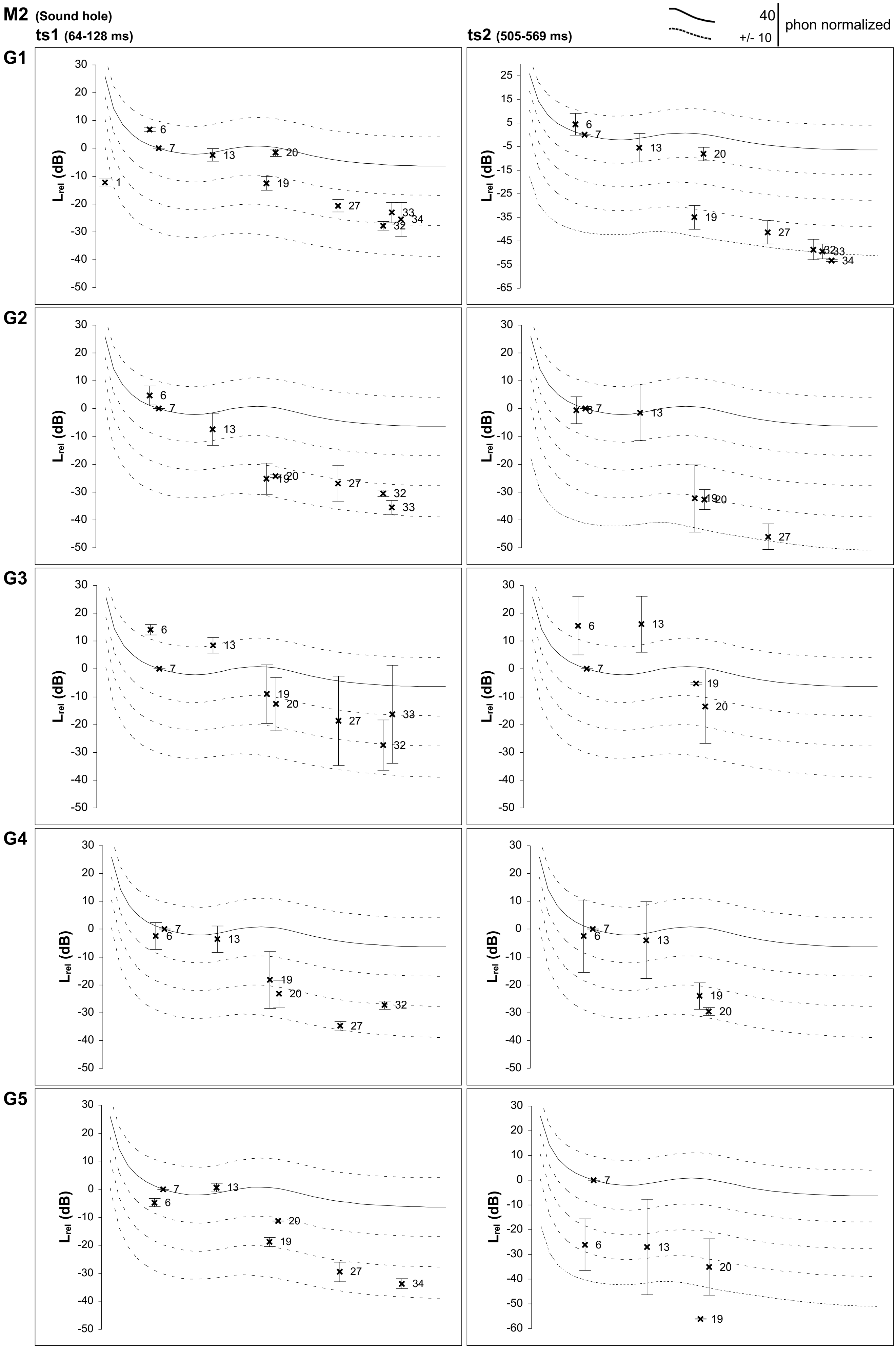


III-
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_rel (dB)

III-
M1 (XII)


ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
L_rel (dB)

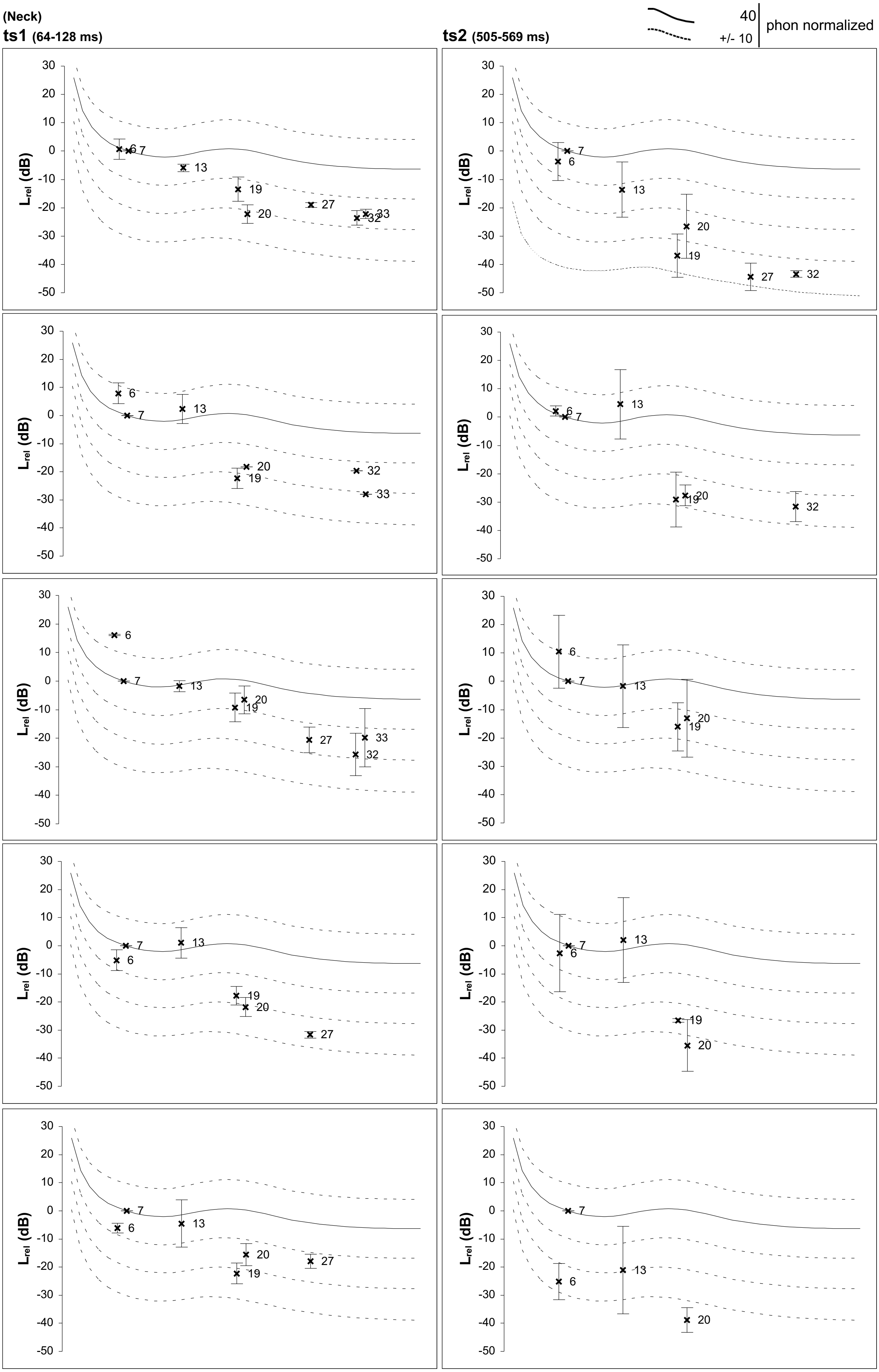
III-
M2 **(Sound hole)**

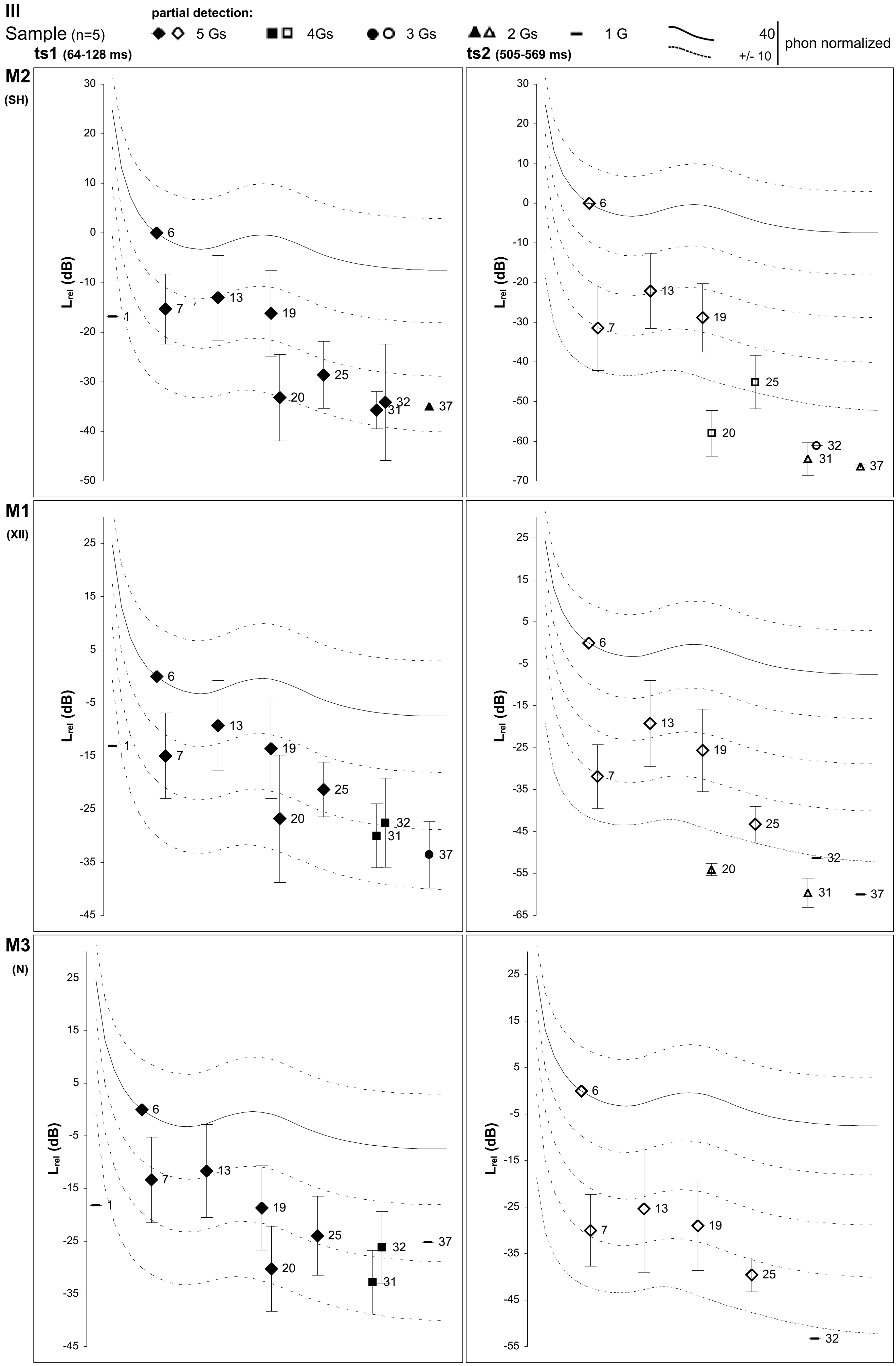


III-
M3 **(Neck)**

ts1 **(64-128 ms)** **ts2** **(505-569 ms)**

G1 **G2** **G3** **G4** **G5**



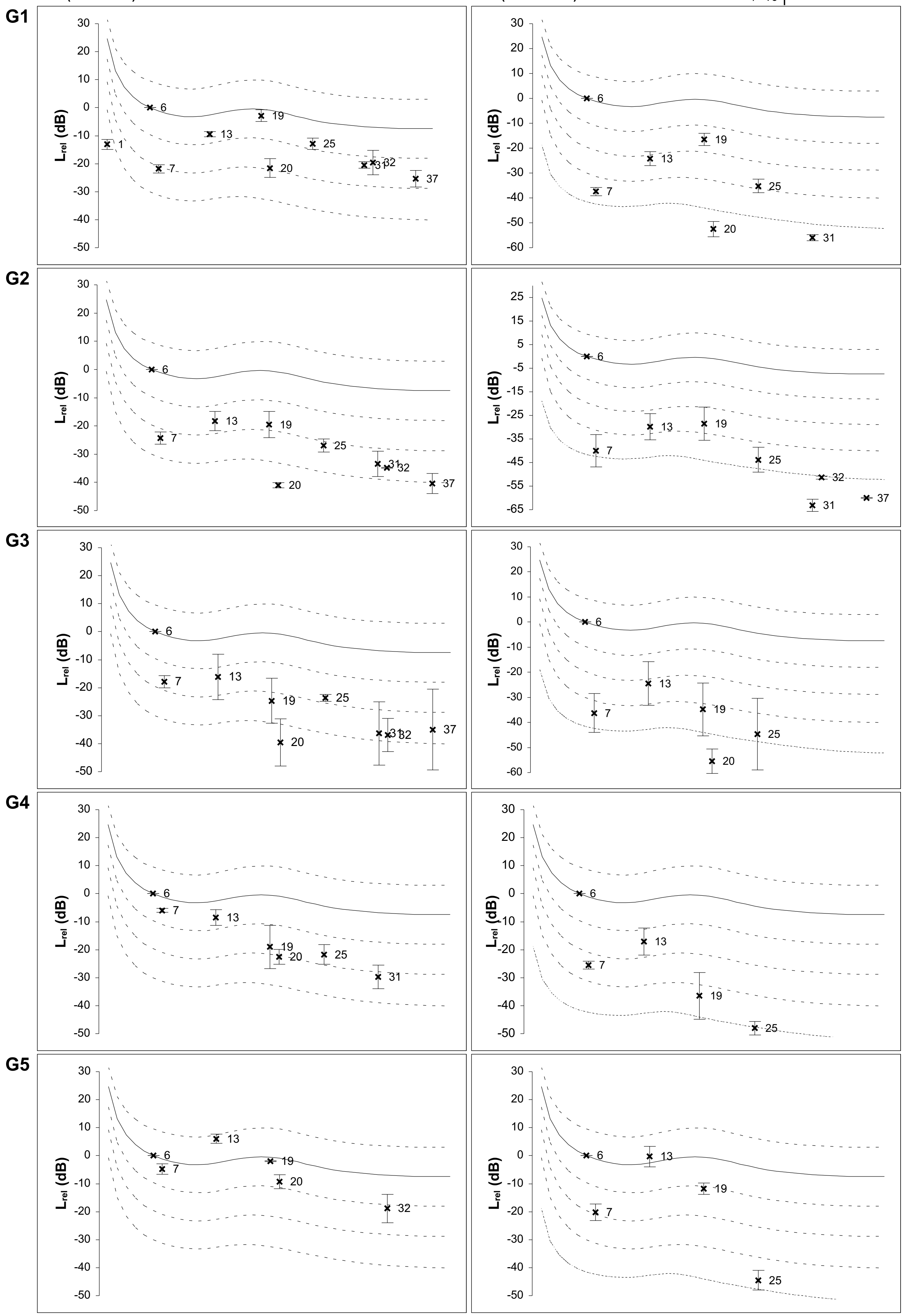

III
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
Lrel (dB)

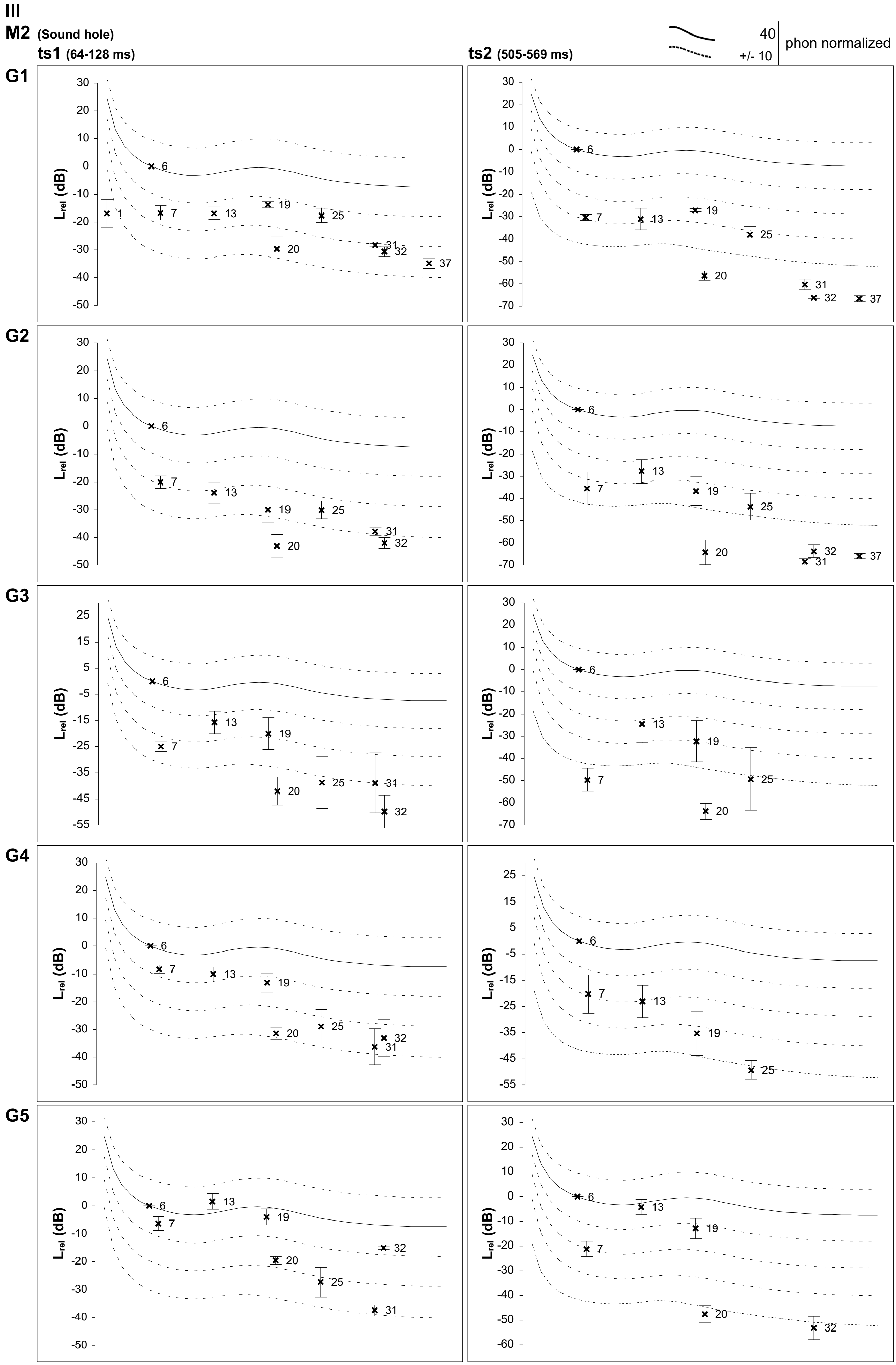
III

M1 (XII)

40 | +/- 10 | phon normalized

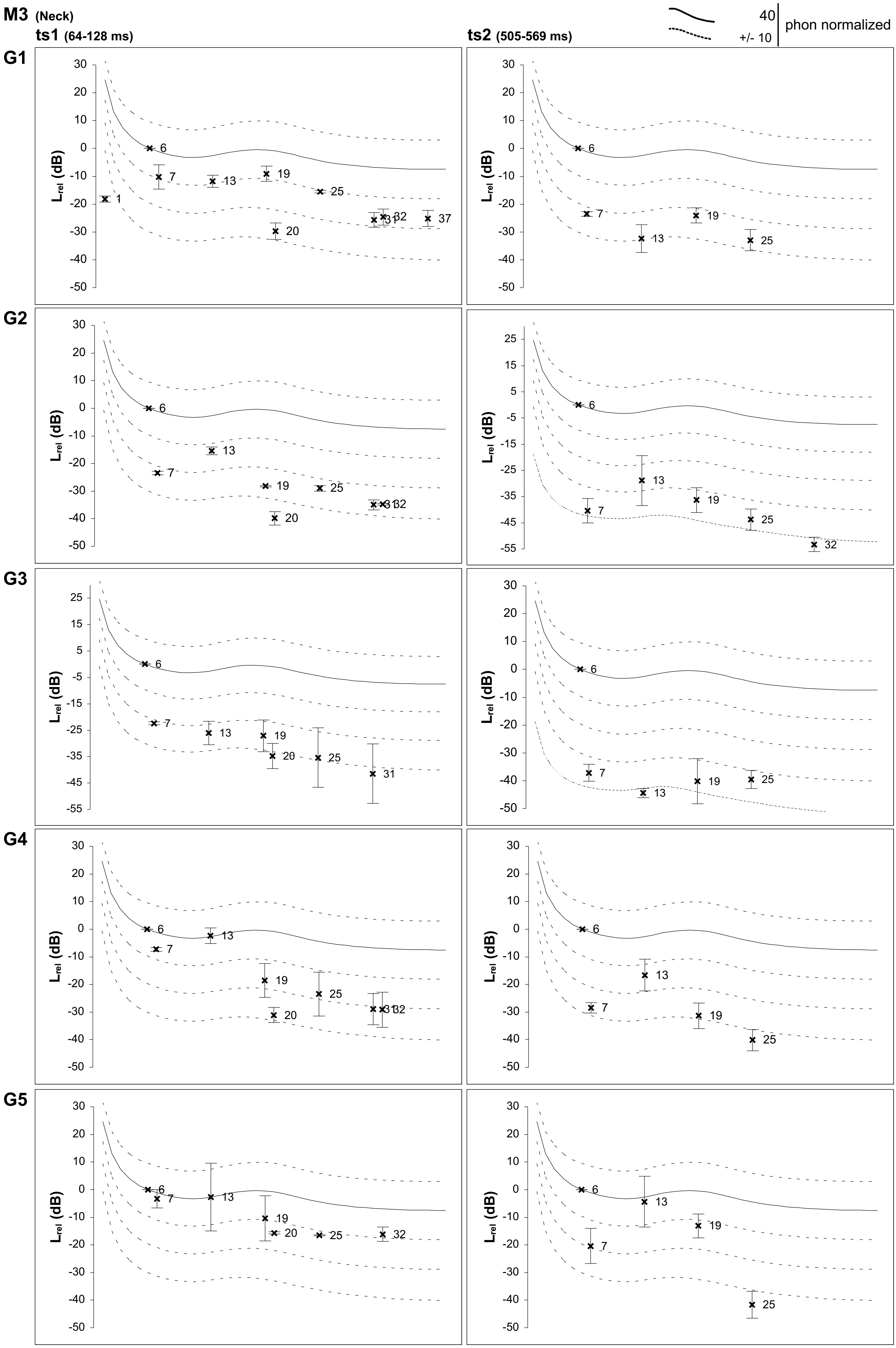
ts1 (64-128 ms) **ts2** (505-569 ms)

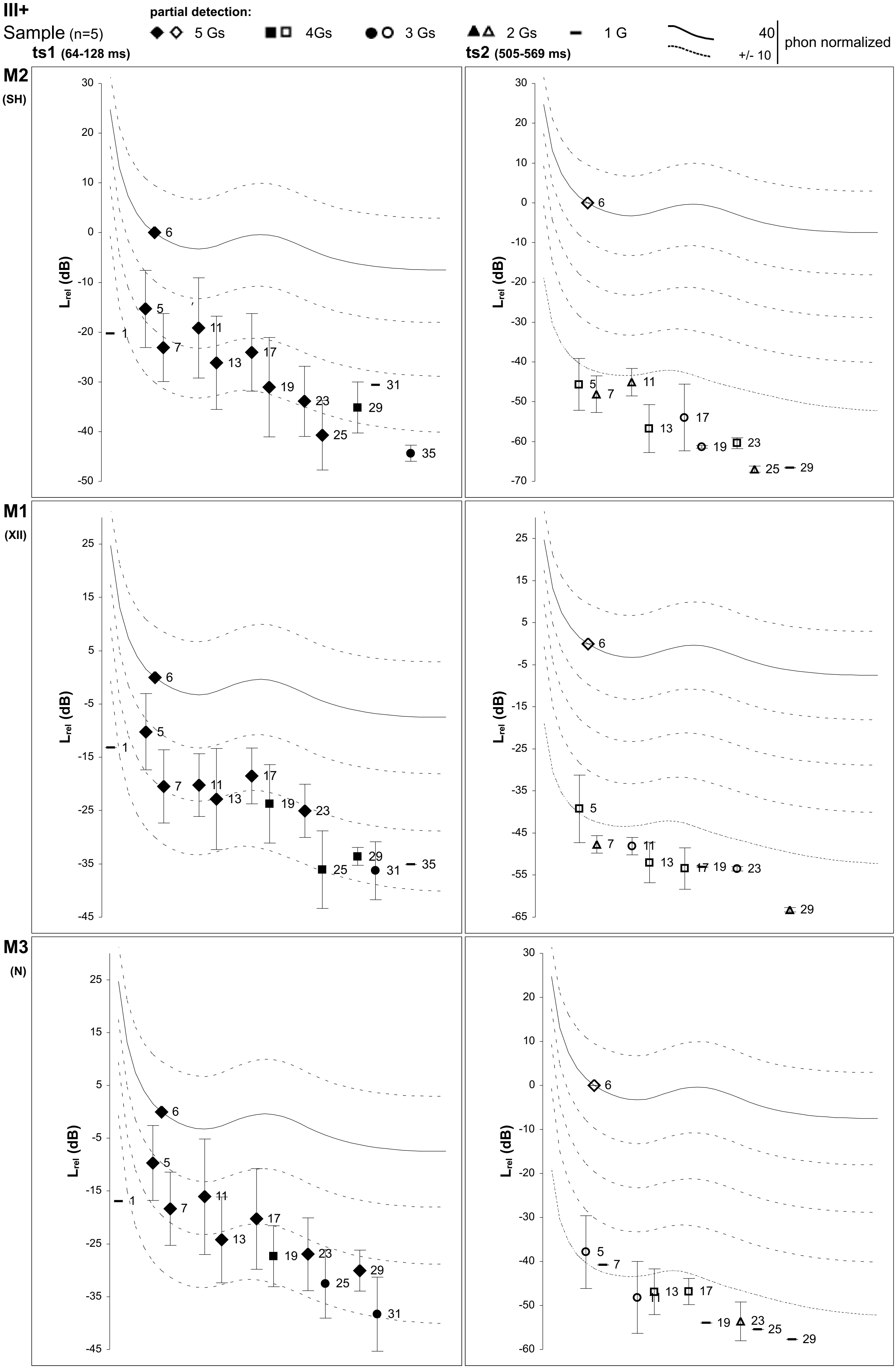



III
M2 (Sound hole)
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
L_{rel} (dB)

III

M3 **(Neck)**

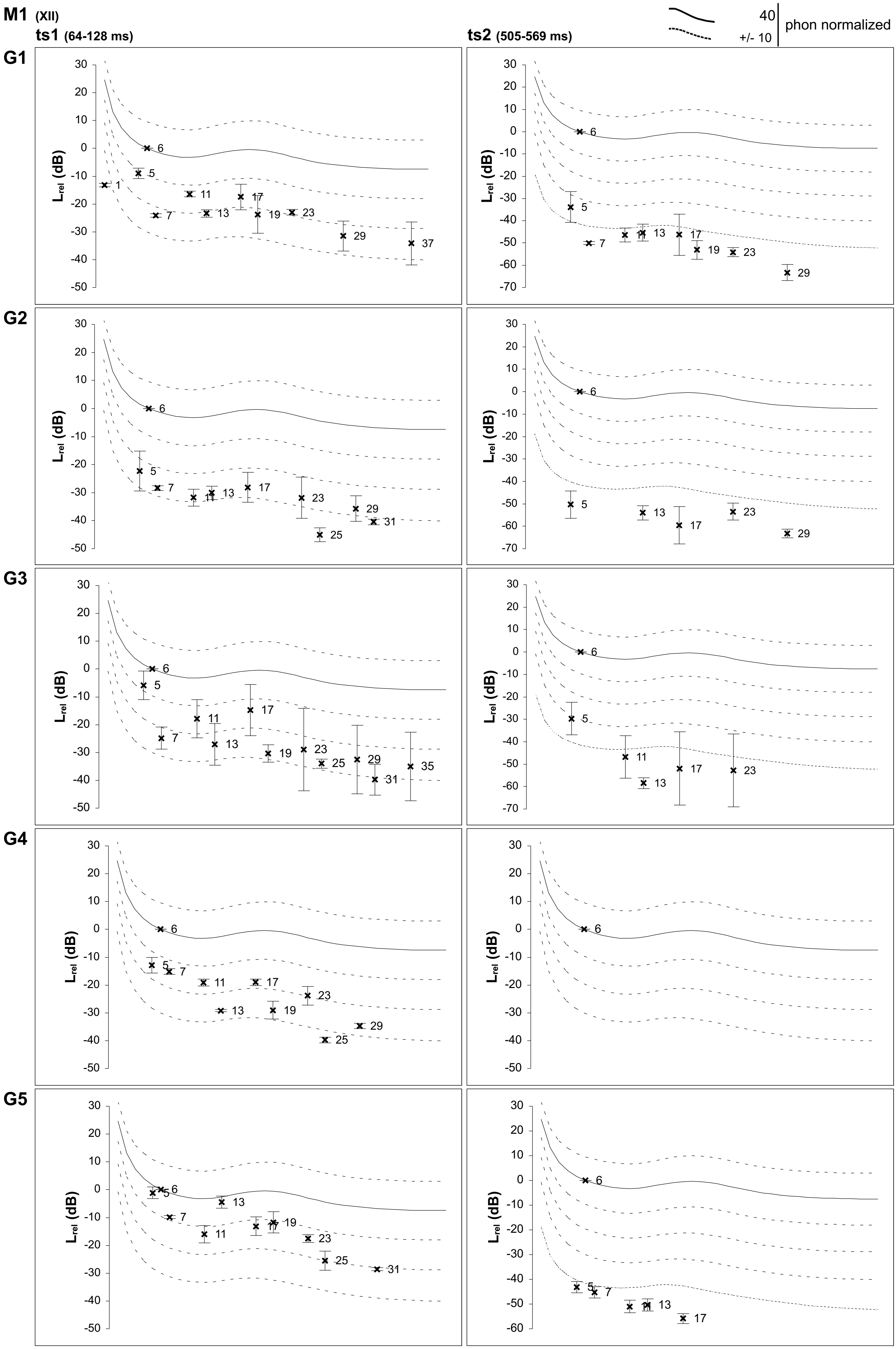

ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
L_{rel} (dB)



III+
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
Lrel (dB)

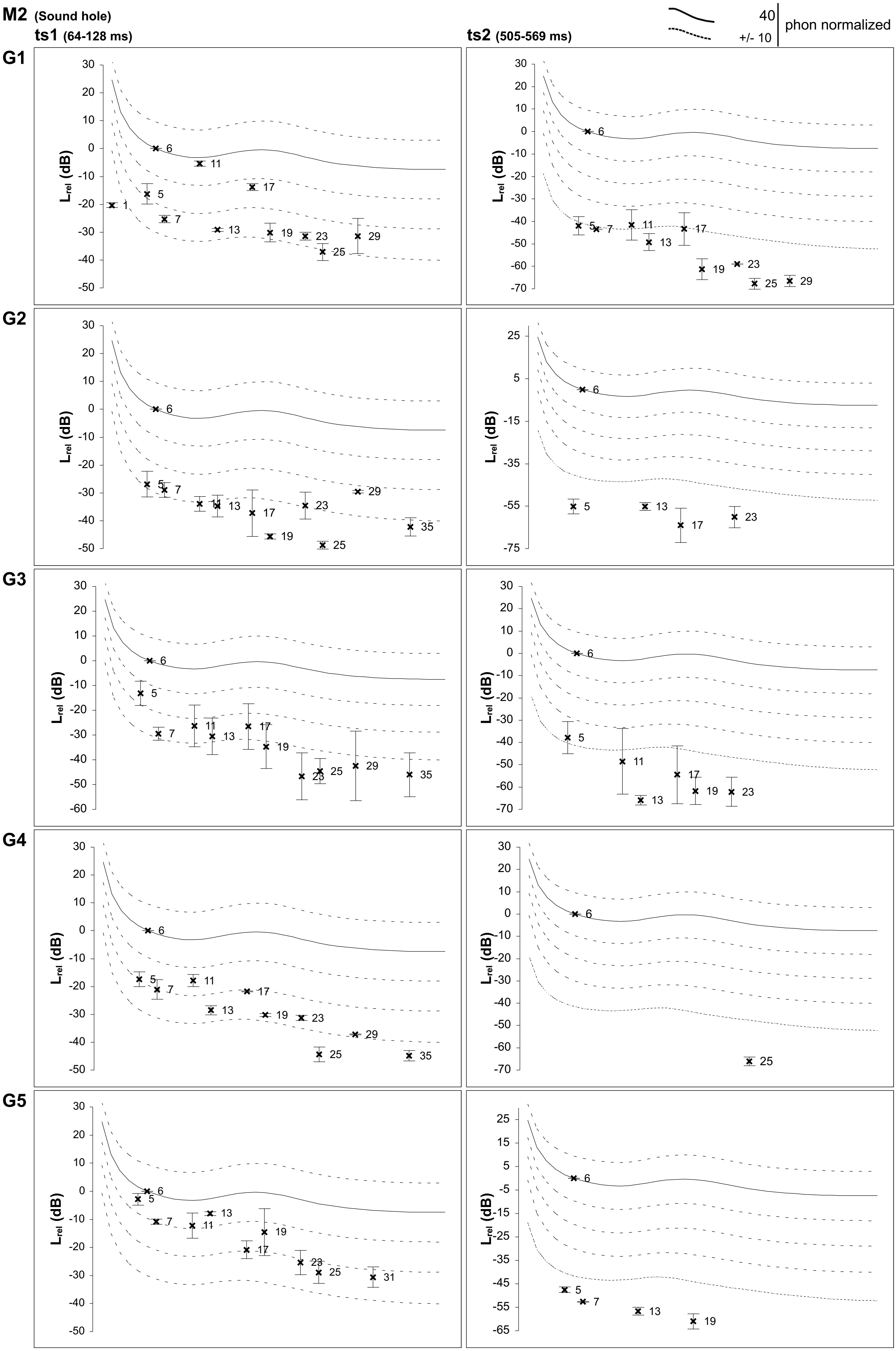
III+

M1 **(XII)**


ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
L_rel (dB)

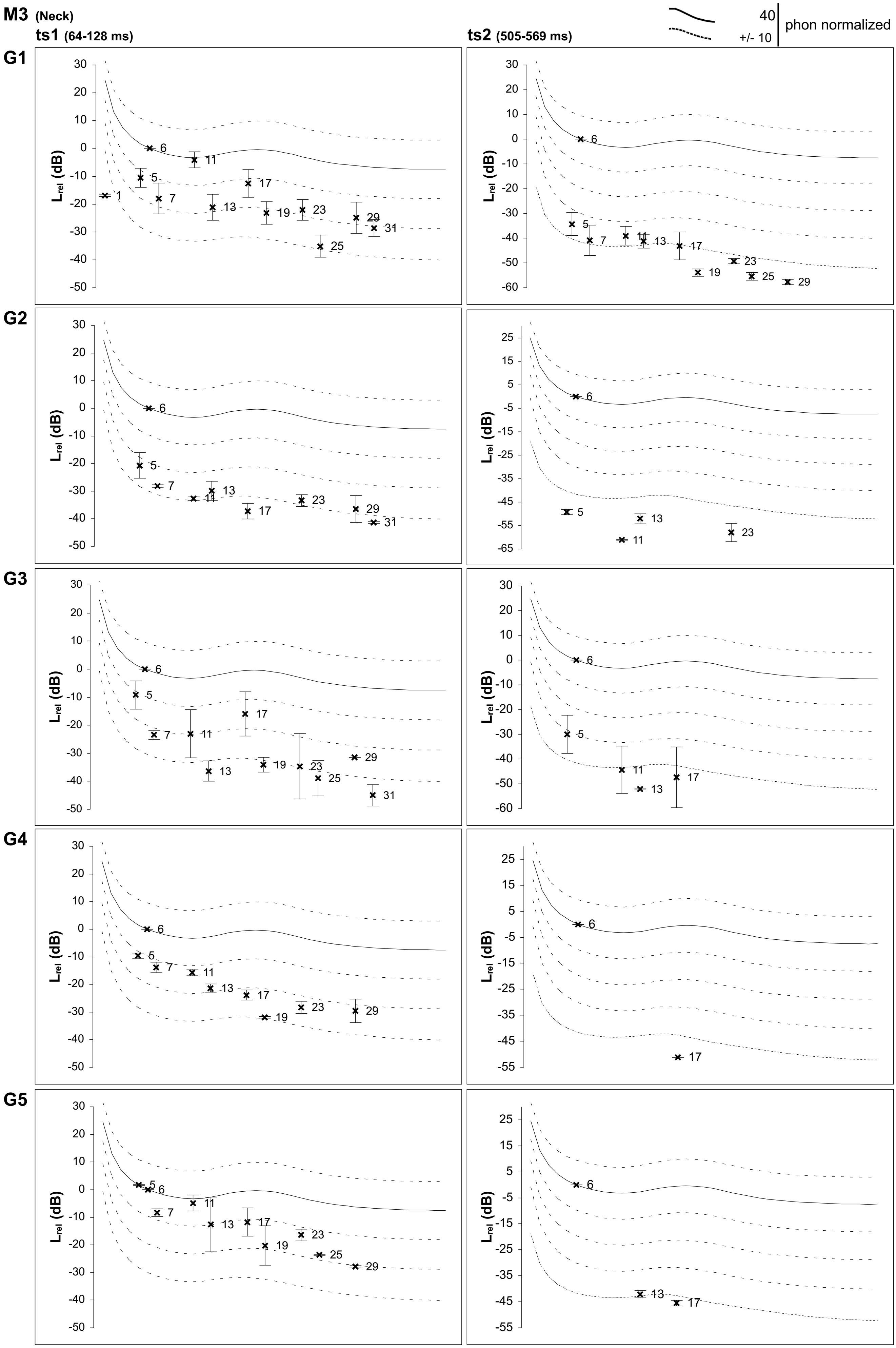
III+

M2 (Sound hole)

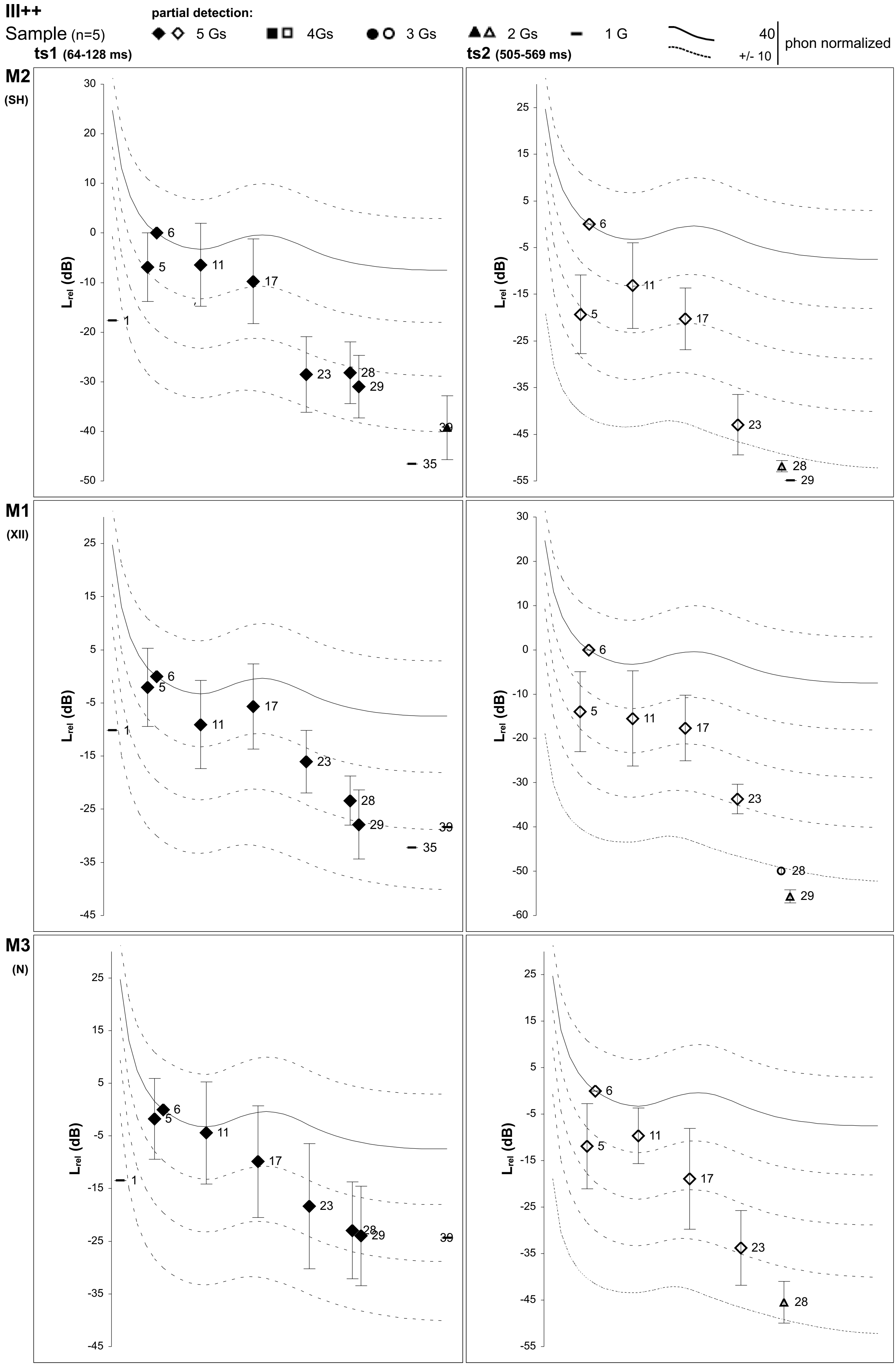


III+

M3 (Neck)



40 phon normalized
+/- 10
ts1 (64-128 ms)
ts2 (505-569 ms)
G1
G2
G3
G4
G5
L_{rel} (dB)


III++
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_{rel} (dB)

III++

M1 (XII)

ts1 (64-128 ms) **ts2** (505-569 ms)

40 / +/- 10 | phon normalized

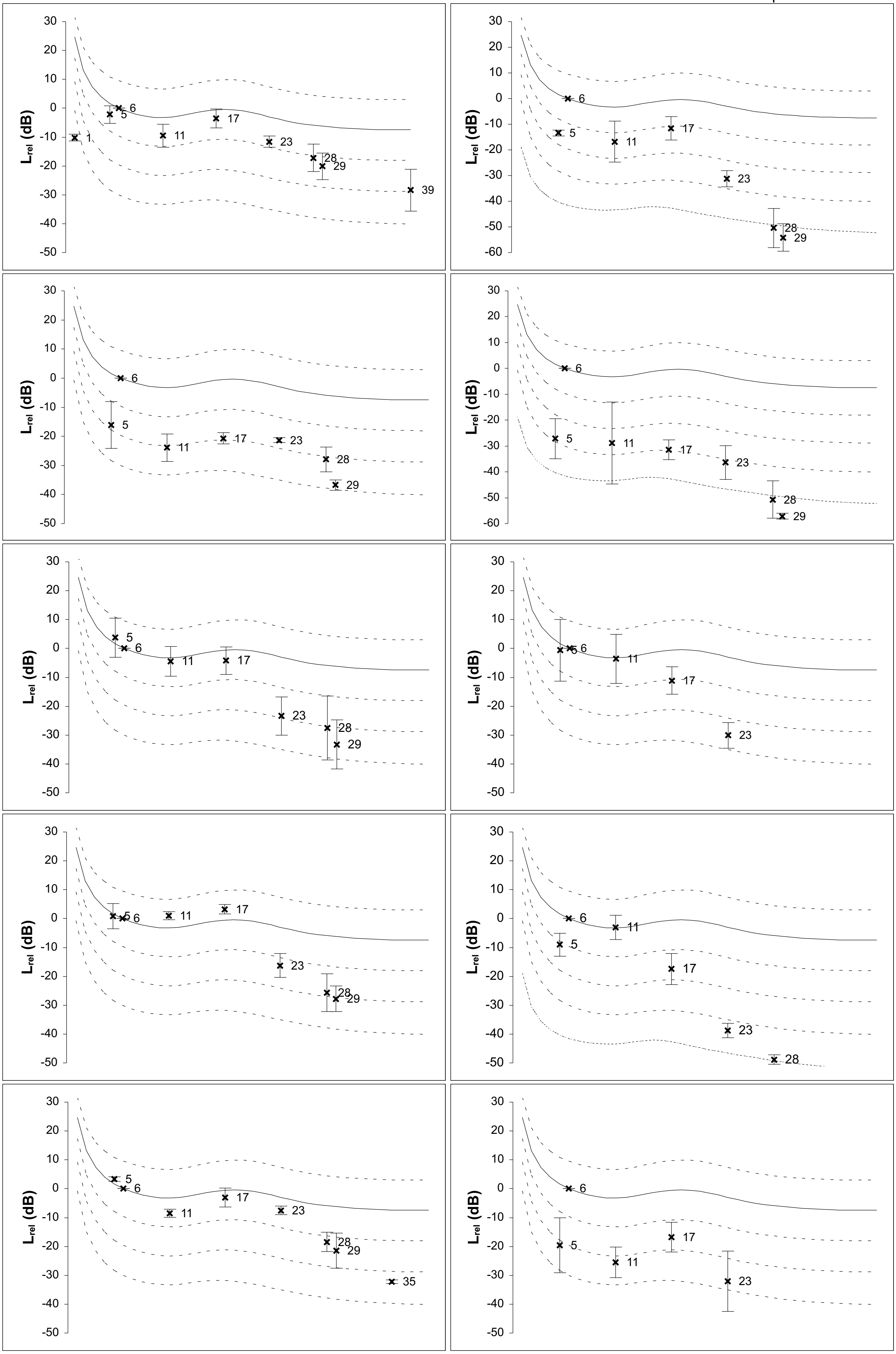
G1

G2

G3

G4

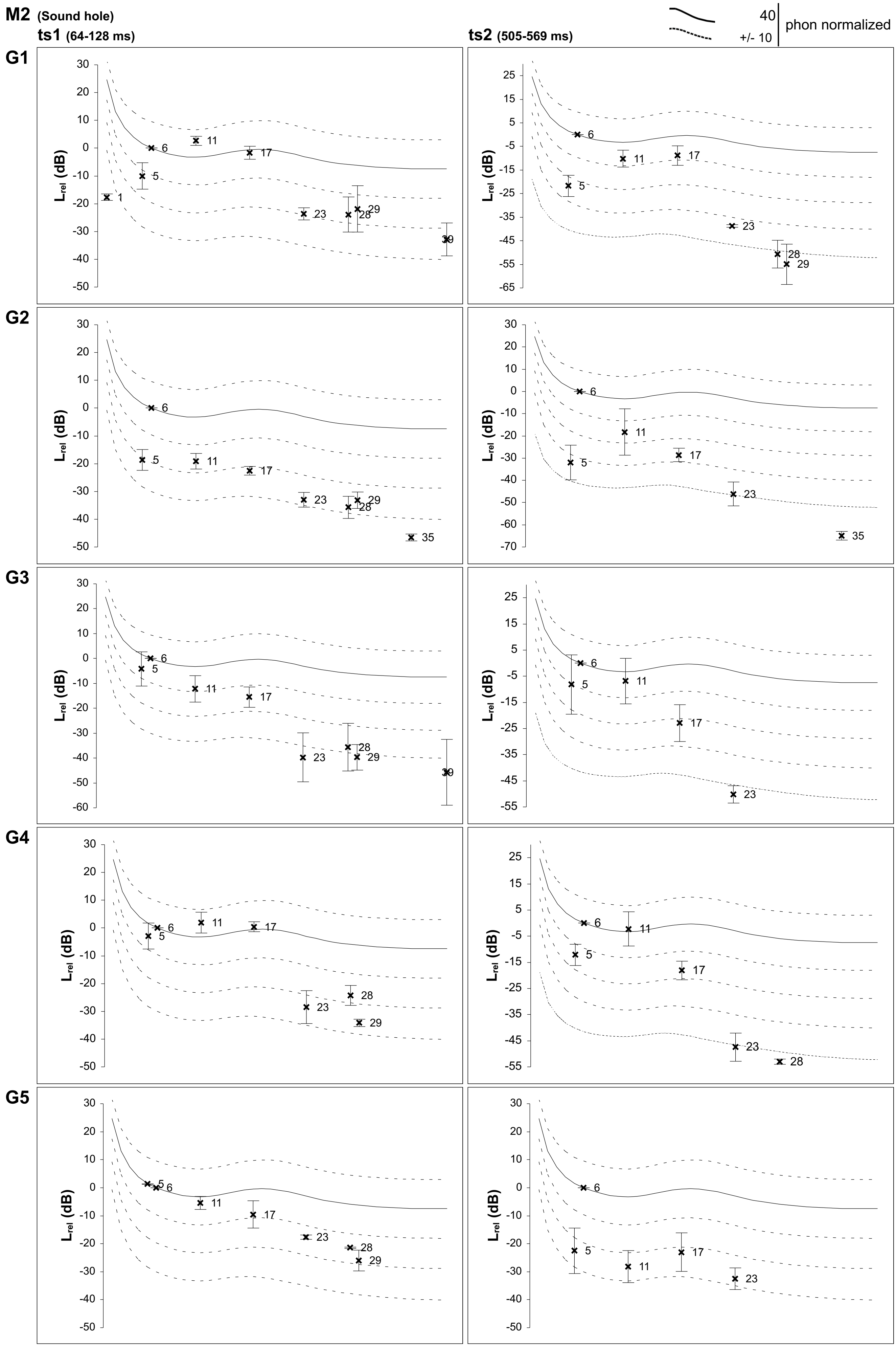
G5



III++

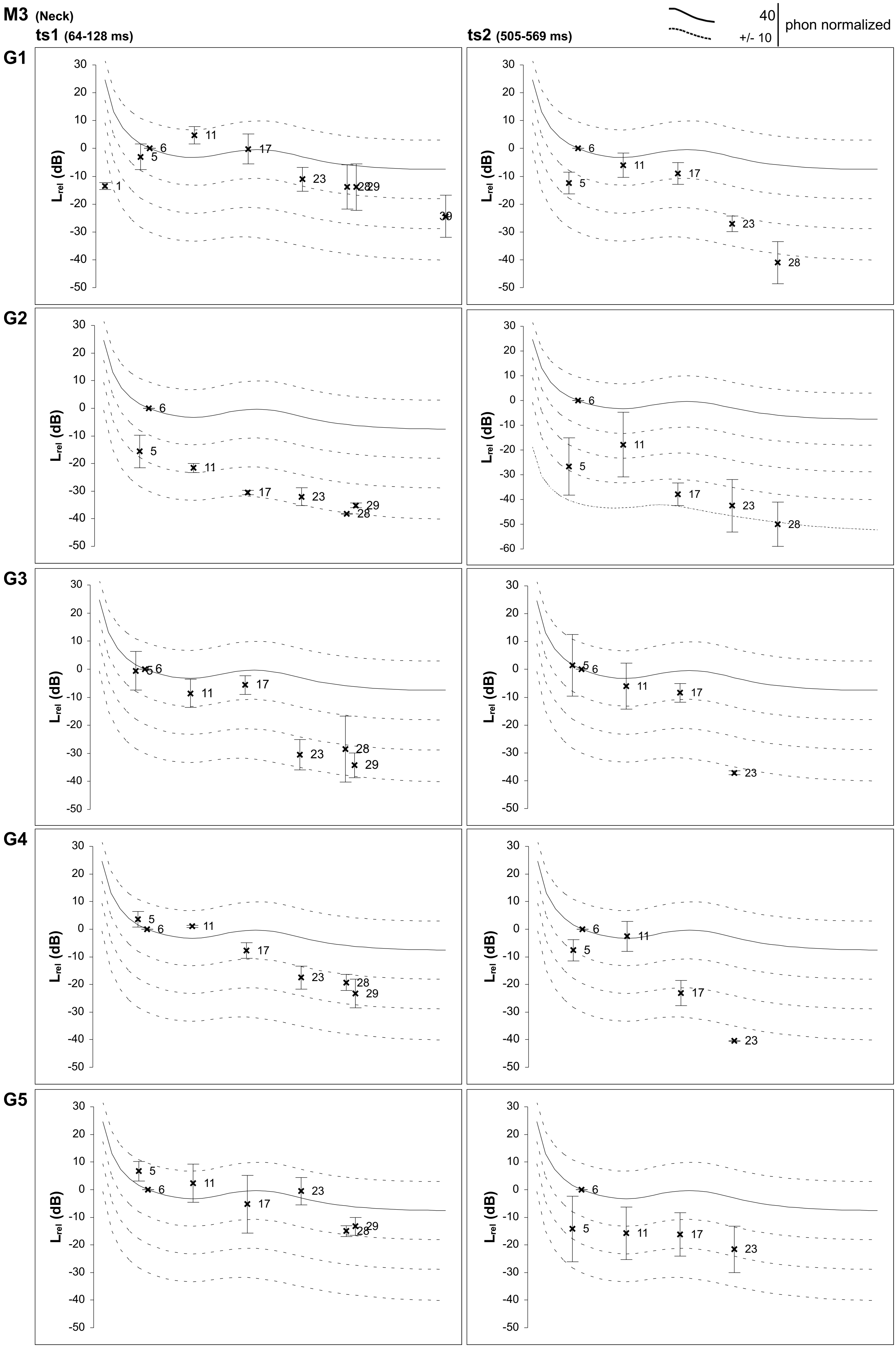
M2 **(Sound hole)**

ts1 **(64-128 ms)** **ts2** **(505-569 ms)**



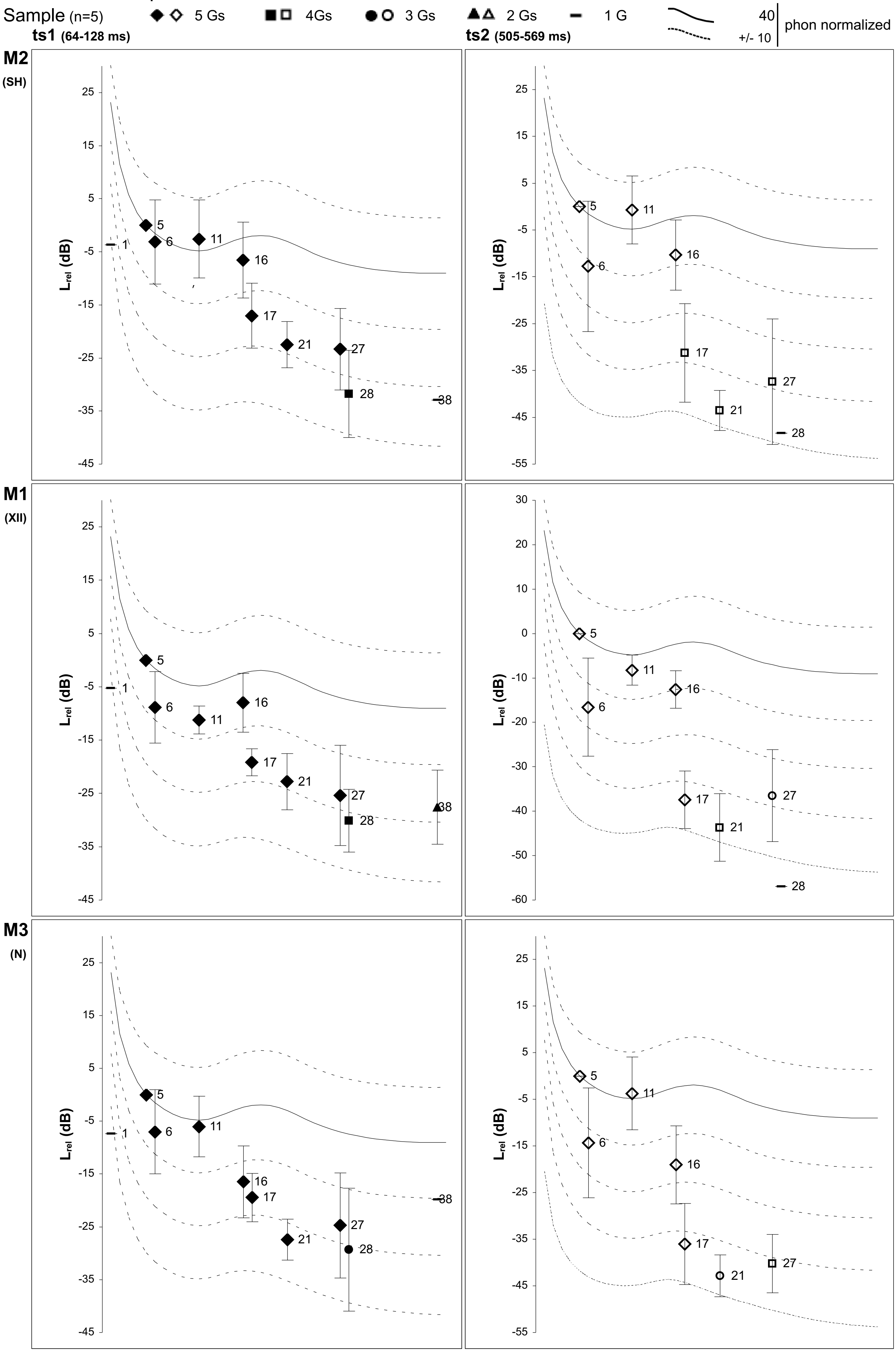
III++

M3 **(Neck)**



40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
G1
G2
G3
G4
G5
L_rel (dB)

III.5


Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_{rel} (dB)

III.5

M1 (XII)

ts1 (64-128 ms) **ts2** (505-569 ms)

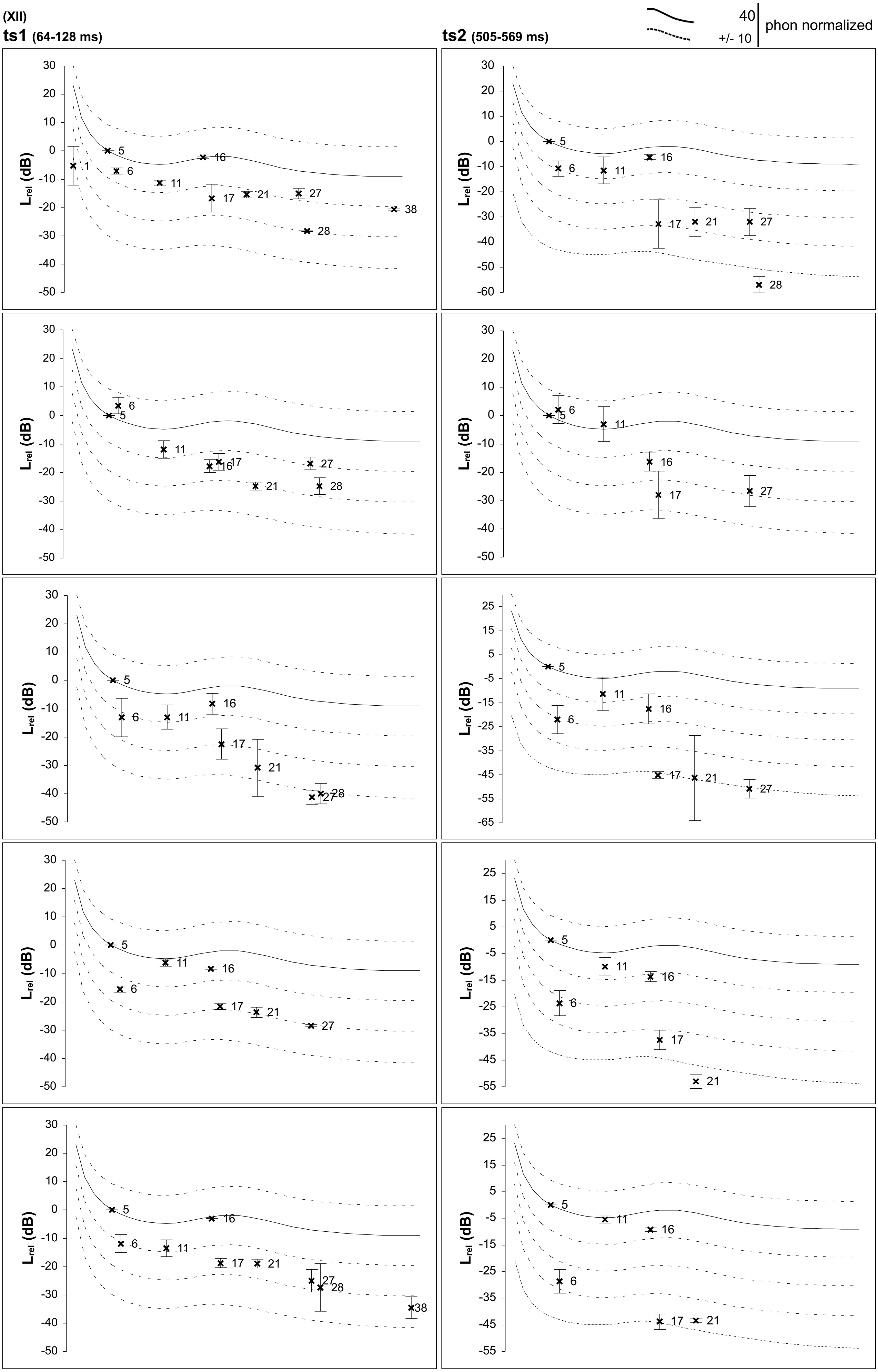
G1

G2

G3

G4

G5

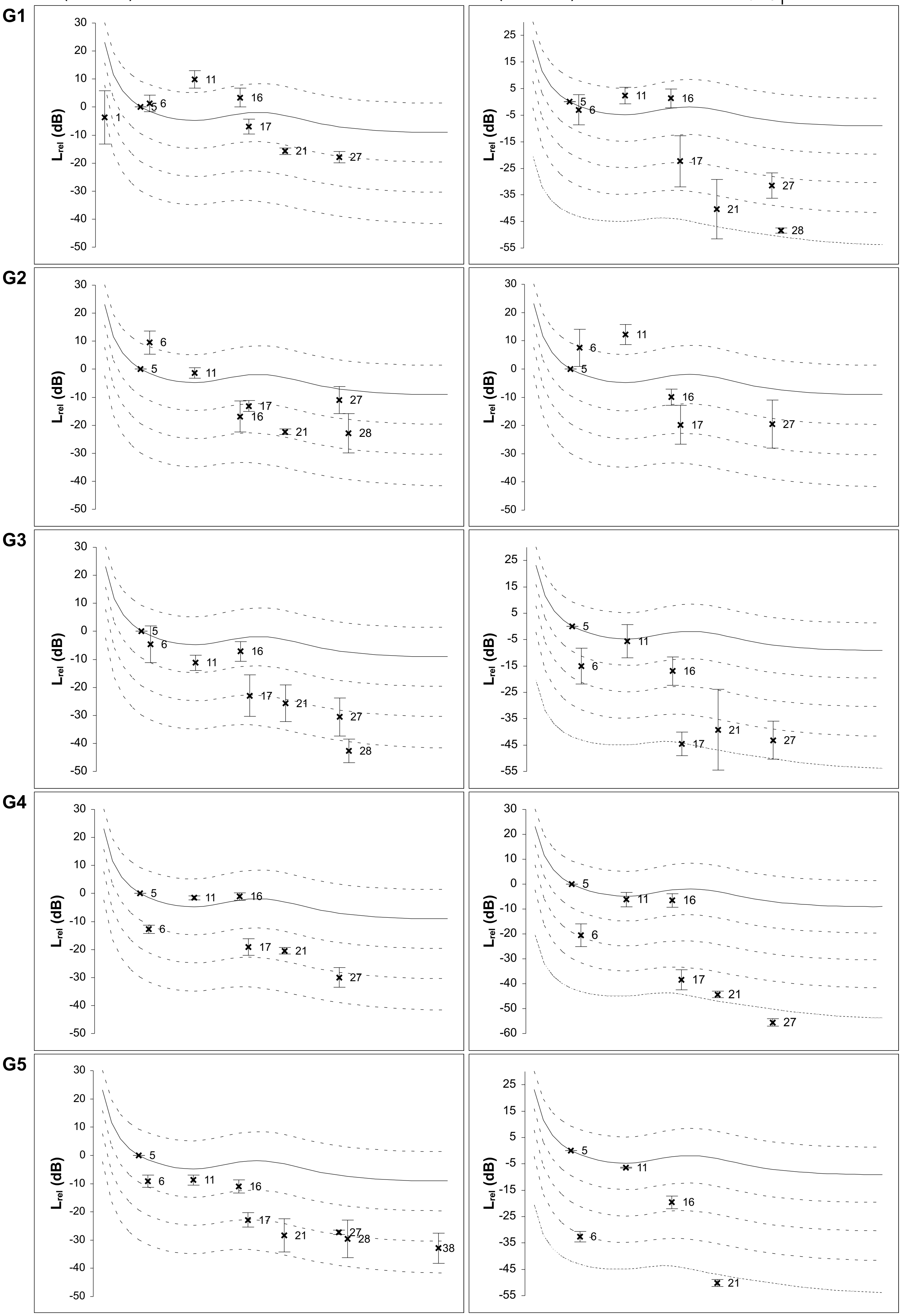


III.5

M2 (Sound hole)

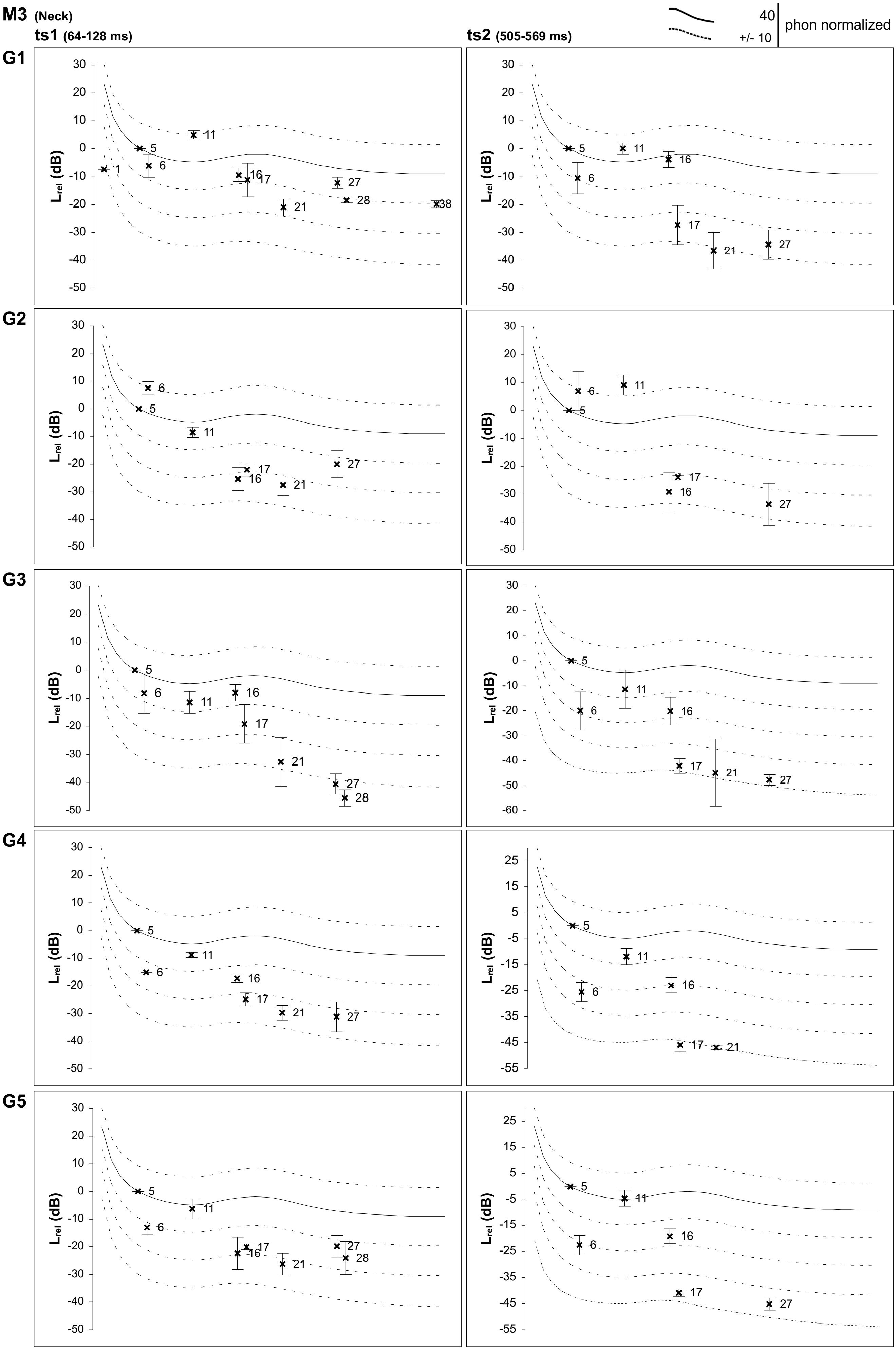
40 / +/- 10 phon normalized

ts1 (64-128 ms) **ts2** (505-569 ms)

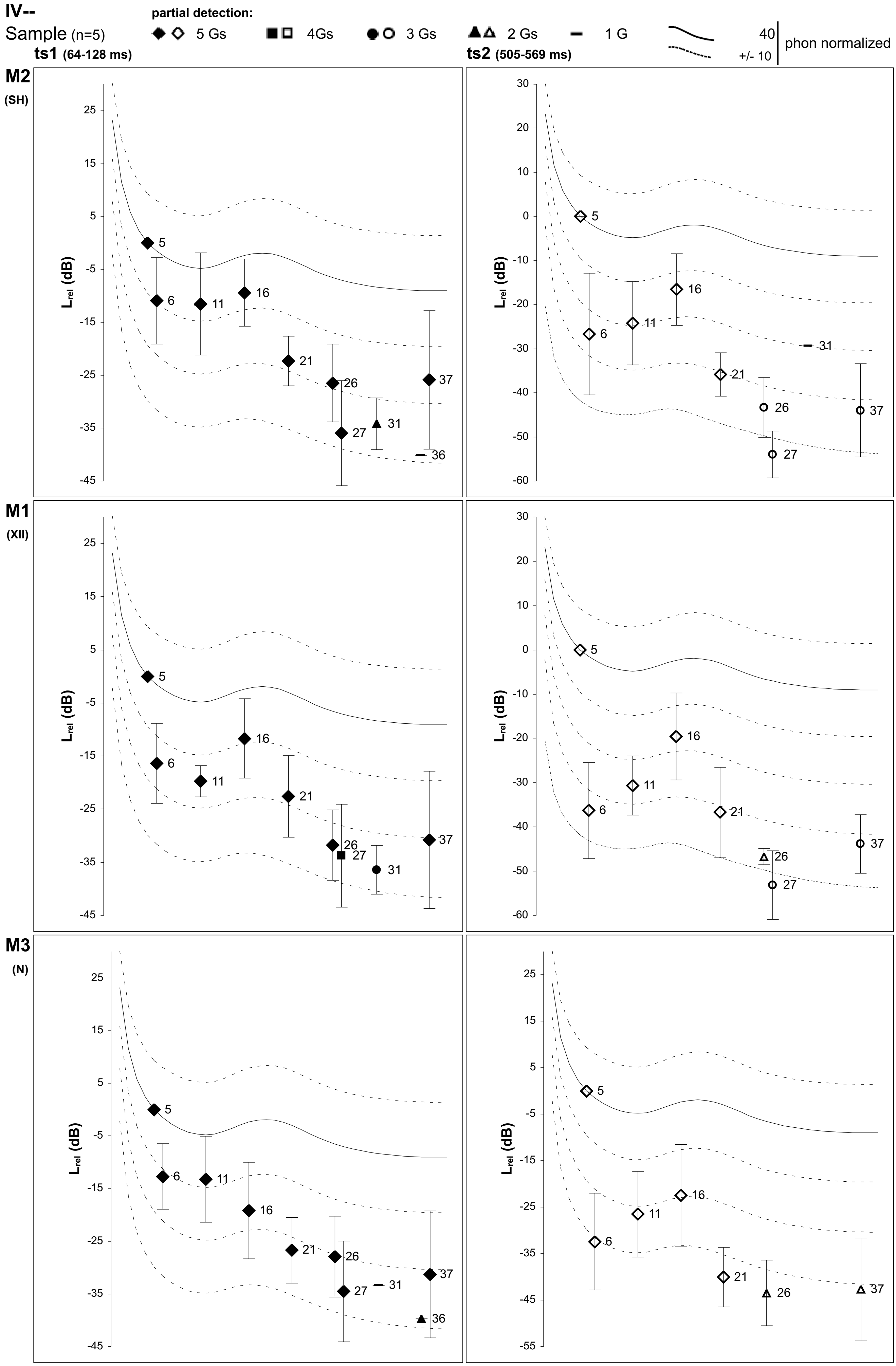


III.5

M3 (Neck)



40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
G1
G2
G3
G4
G5
Lrel (dB)


IV--
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_{rel} (dB)

IV--

M1 (XII)

40 / +/- 10 phon normalized

ts1 (64-128 ms) **ts2** (505-569 ms)

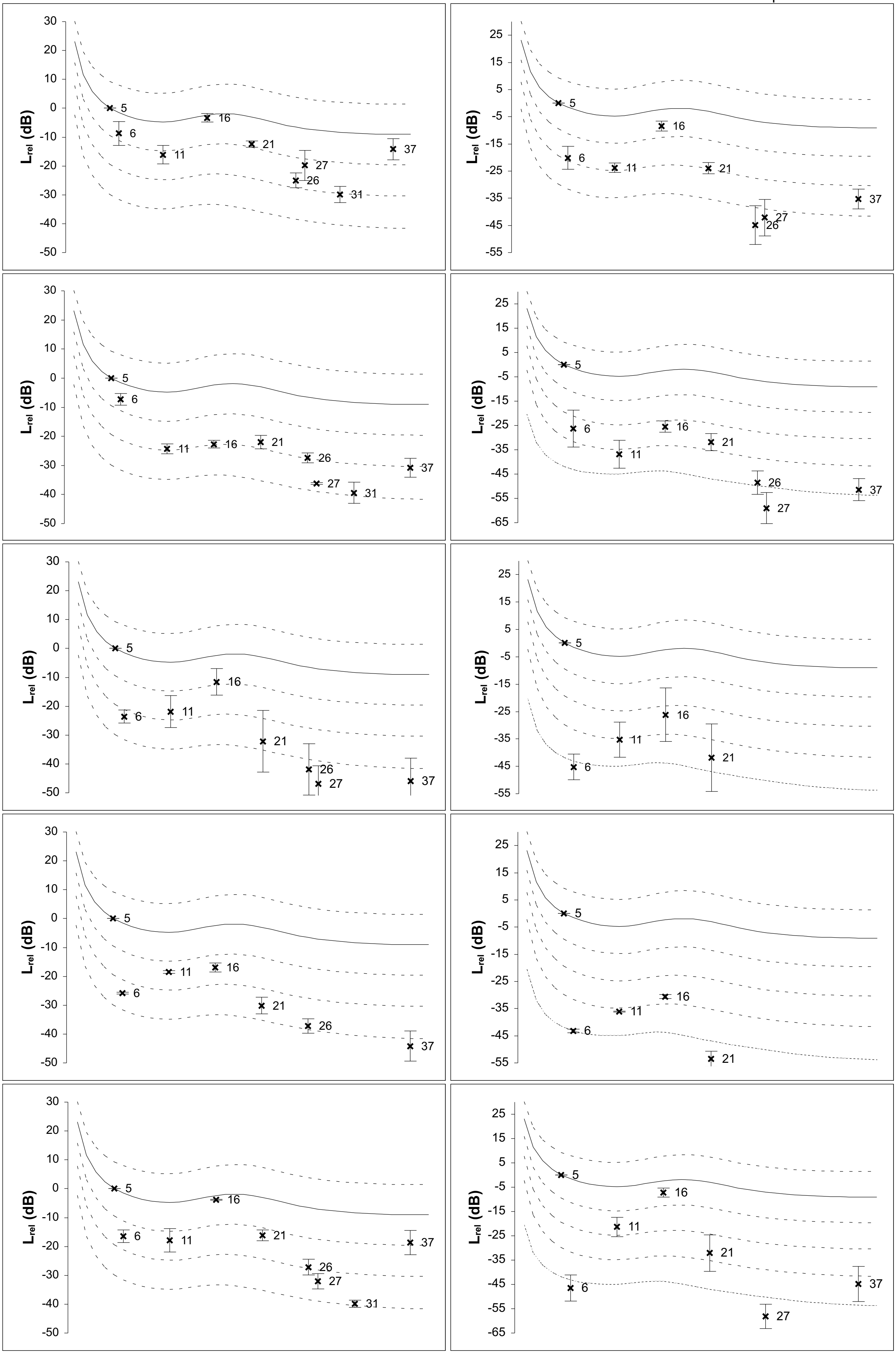
G1

G2

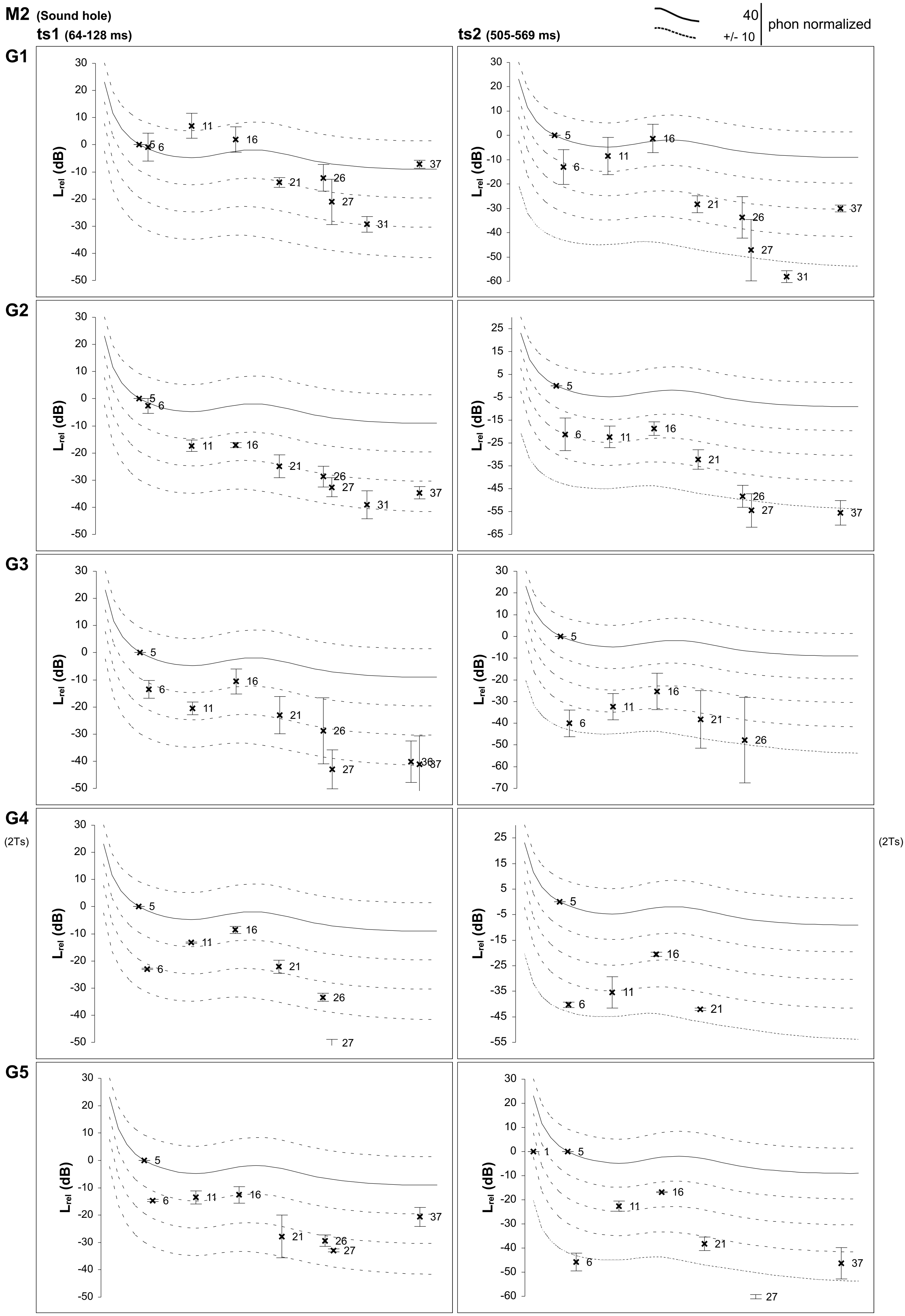
G3

G4 (2Ts)

G5



IV--


M2 (Sound hole)
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
(2Ts)
G5
(2Ts)
Lrel (dB)

IV--

M3 (Neck)

40 / +/- 10 phon normalized

ts1 (64-128 ms) **ts2** (505-569 ms)

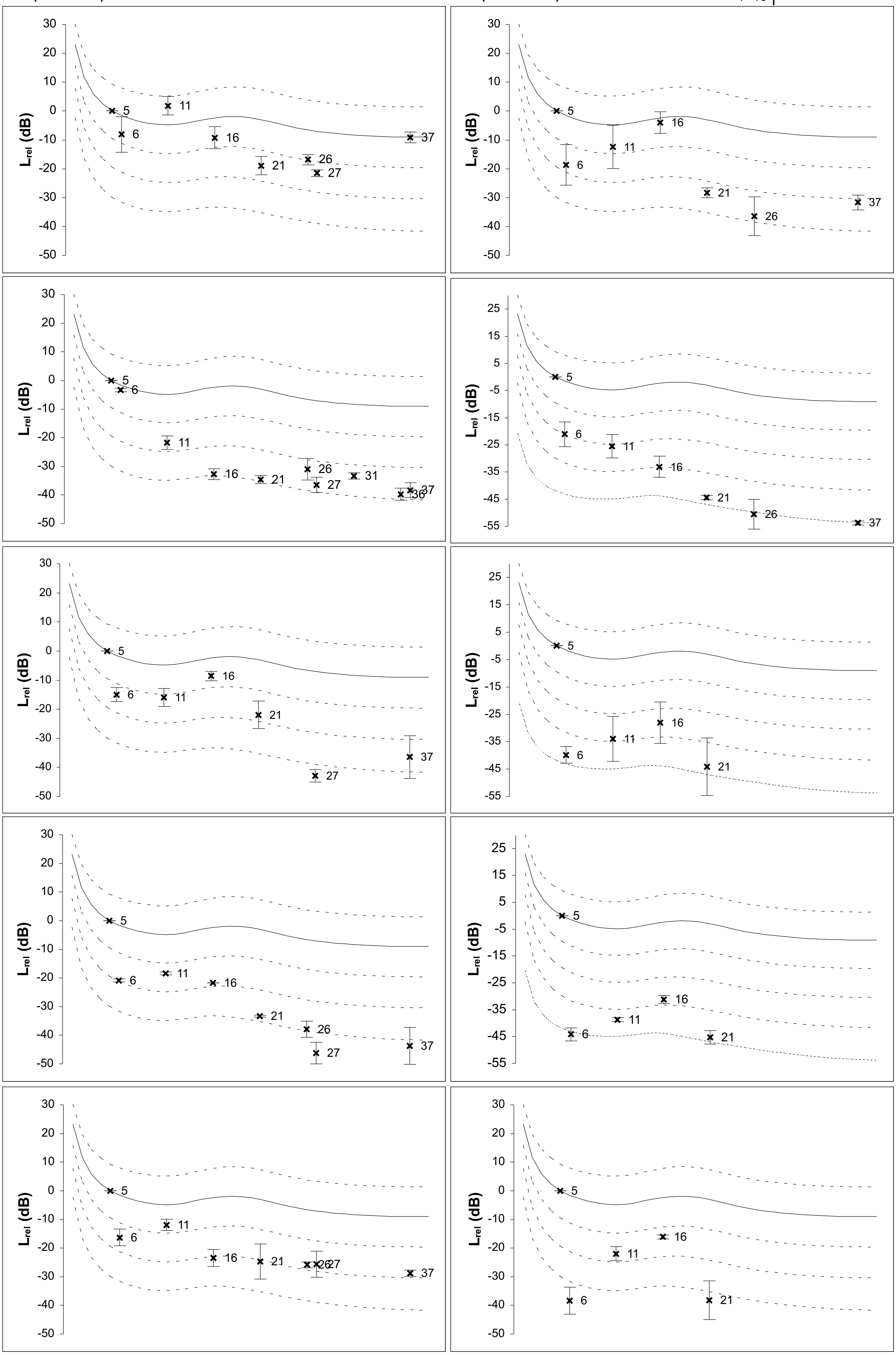
G1

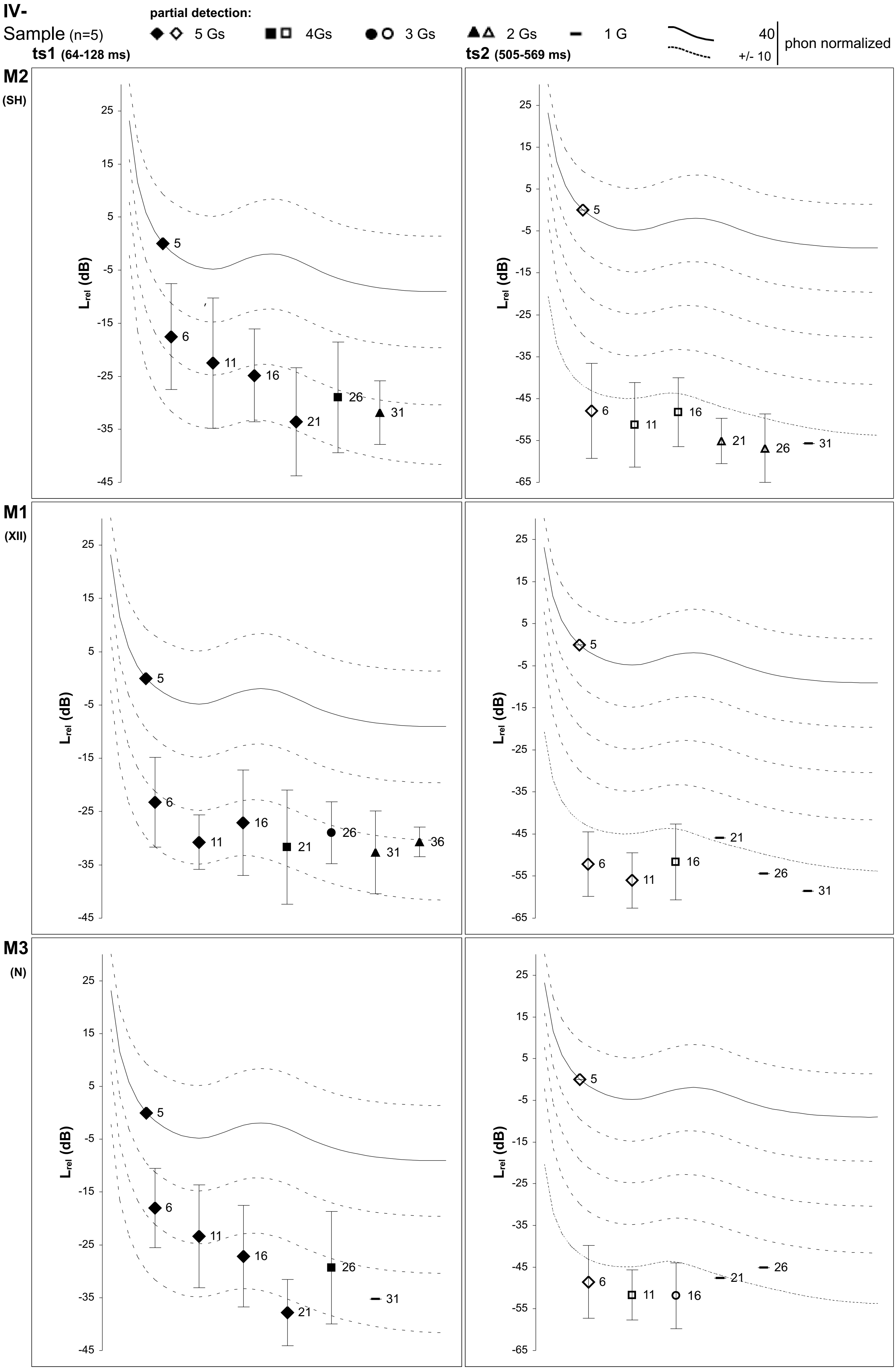
G2

G3 (2Ts)

G4 (2Ts) (2Ts)

G5



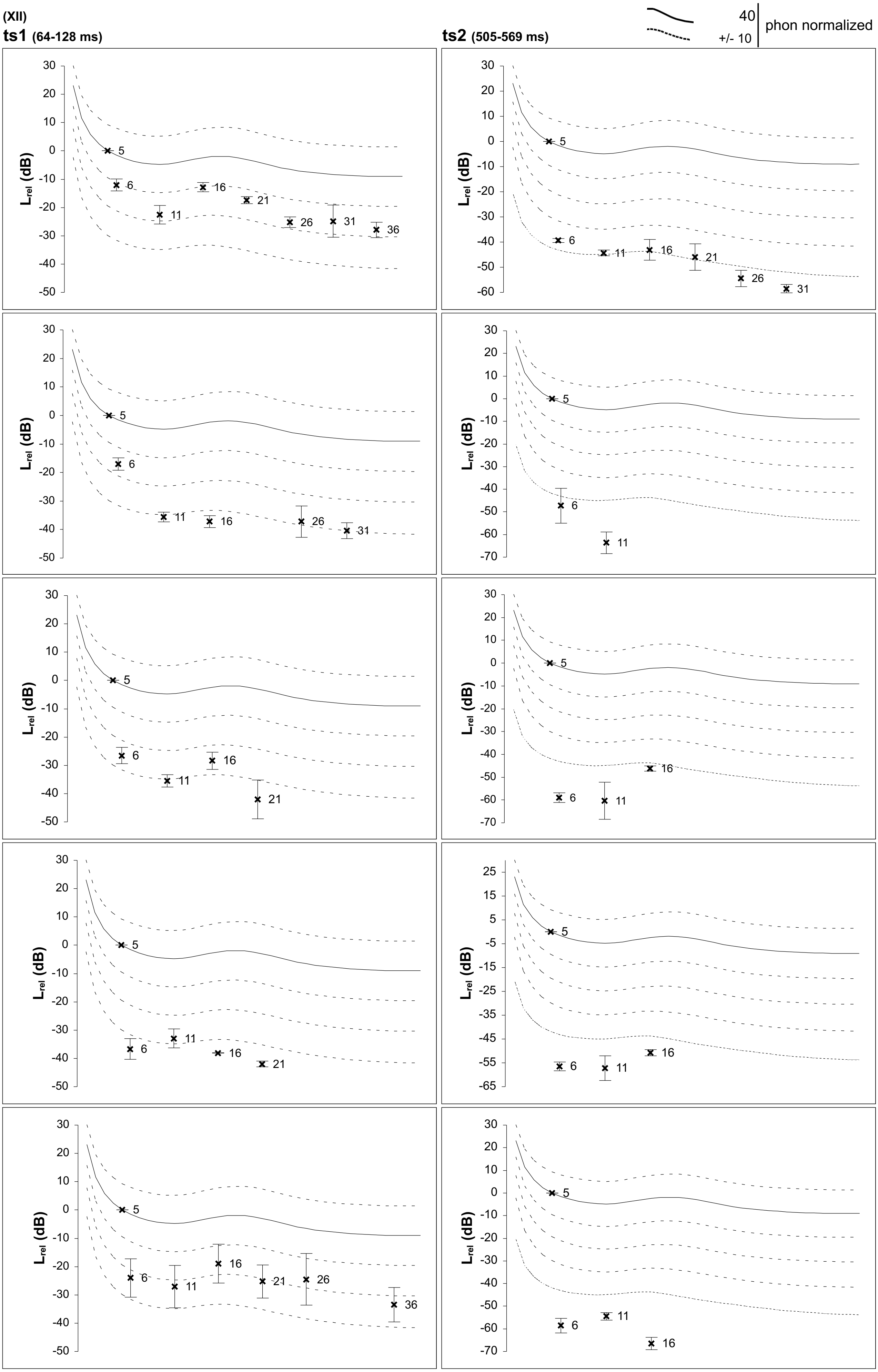


IV-
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_{rel} (dB)

IV-
M1 **(XII)**

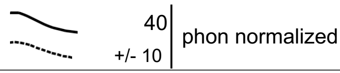
ts1 **(64-128 ms)** **ts2** **(505-569 ms)**

G1
G2
G3
G4
G5

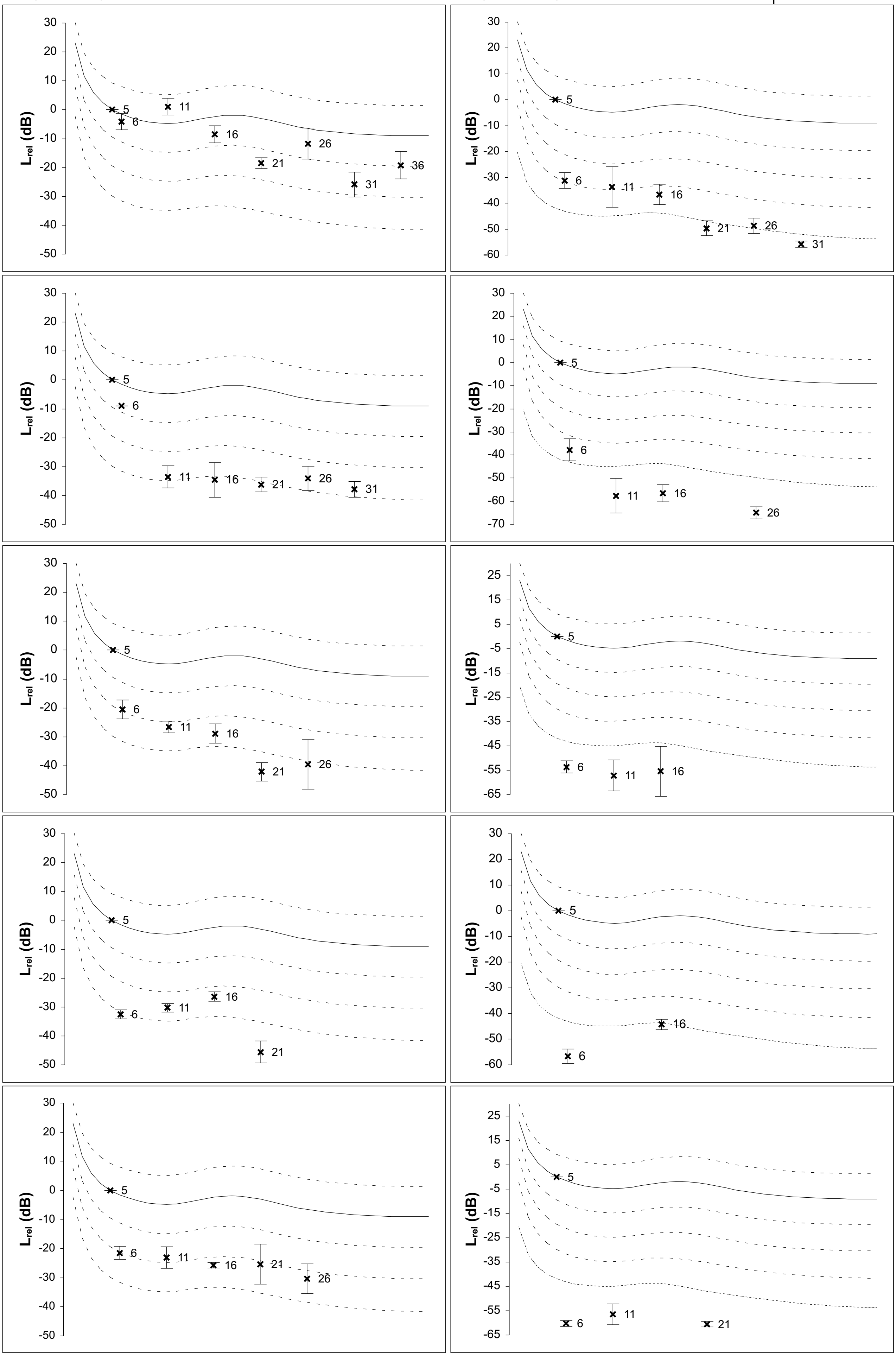


IV-
M2 (Sound hole)

ts1 (64-128 ms) **ts2** (505-569 ms)



G1
G2
G3
G4
G5

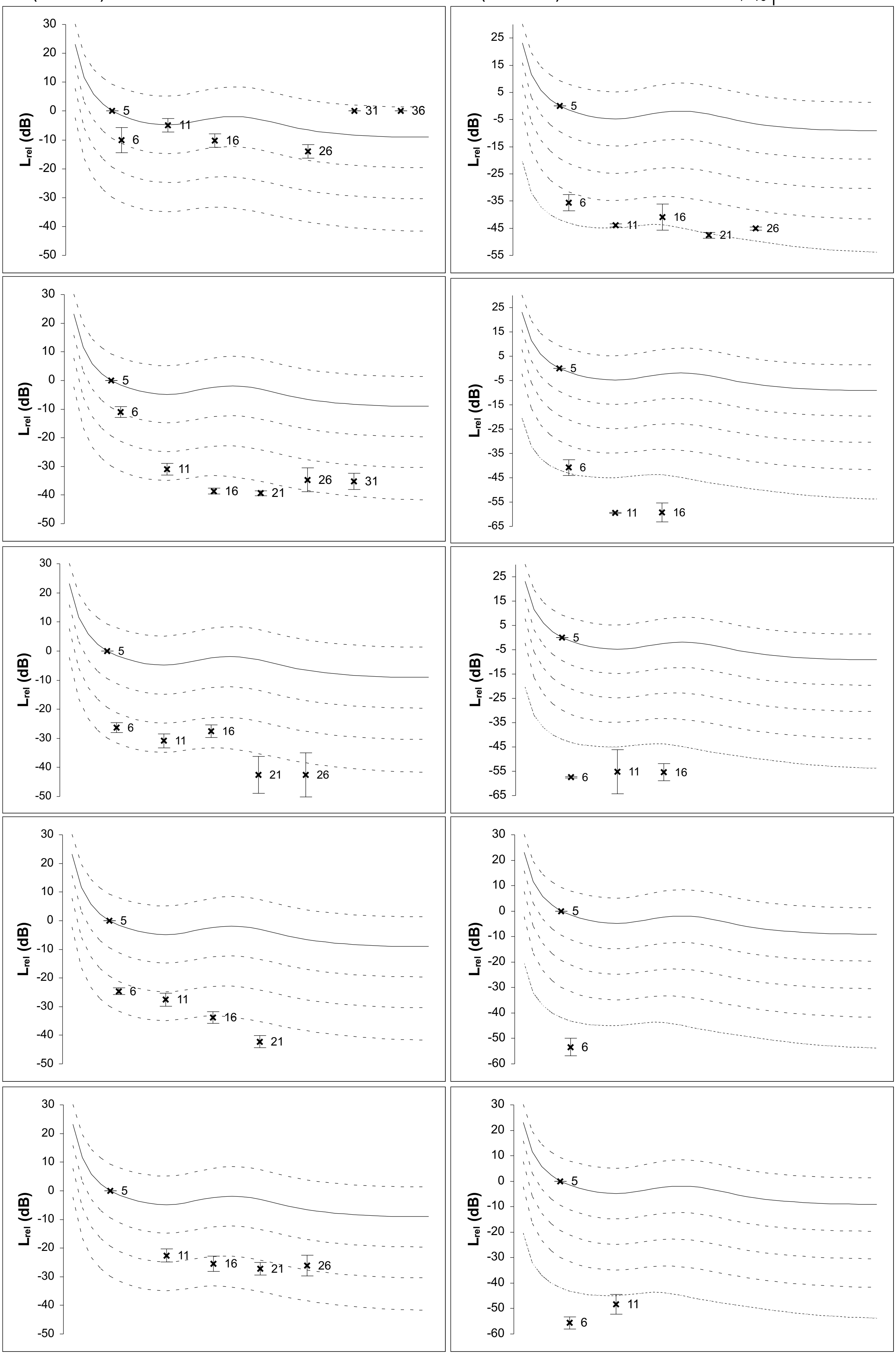


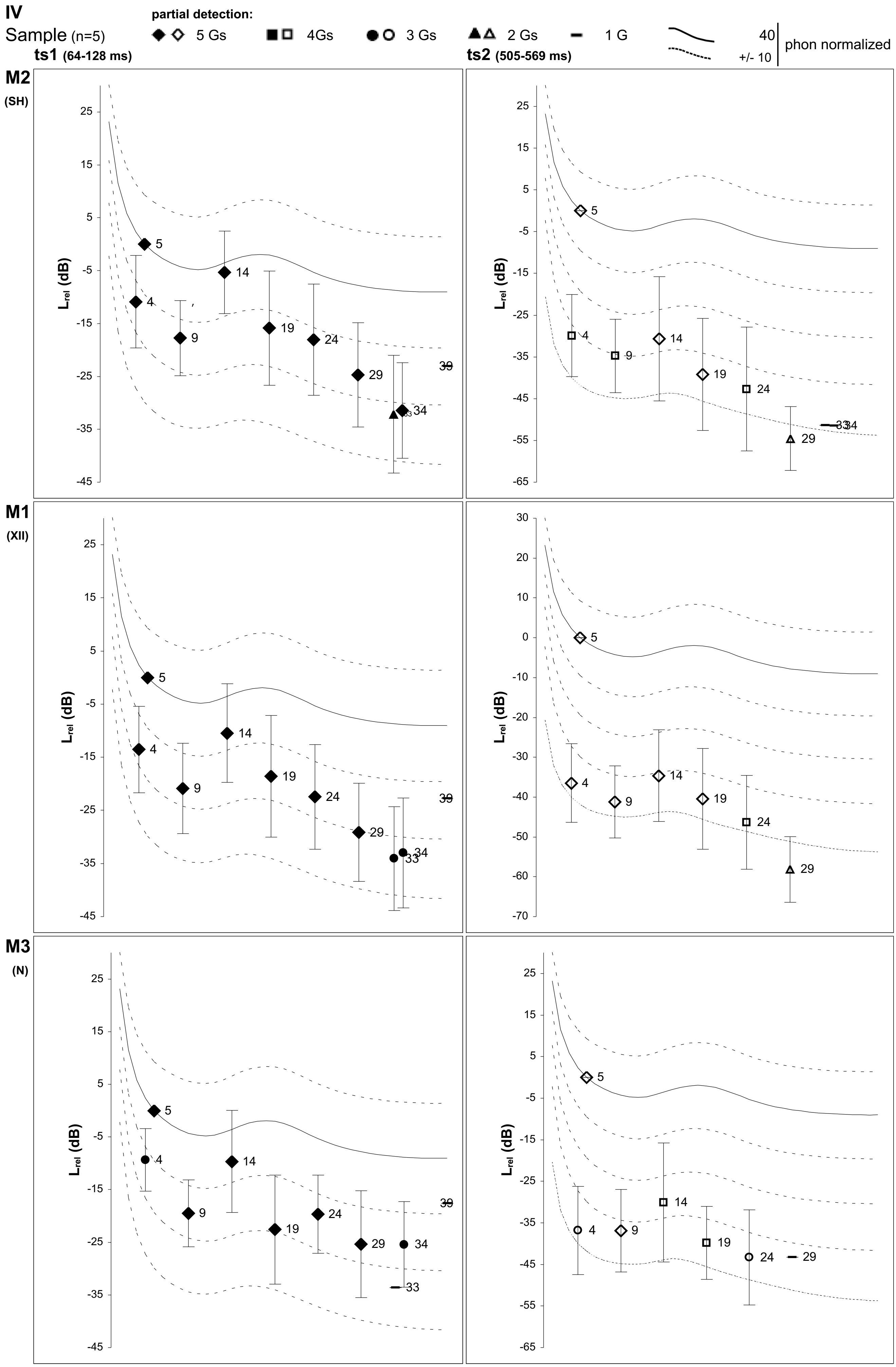
IV-
M3 (Neck)

ts1 (64-128 ms) ts2 (505-569 ms)

40 / +/- 10 phon normalized

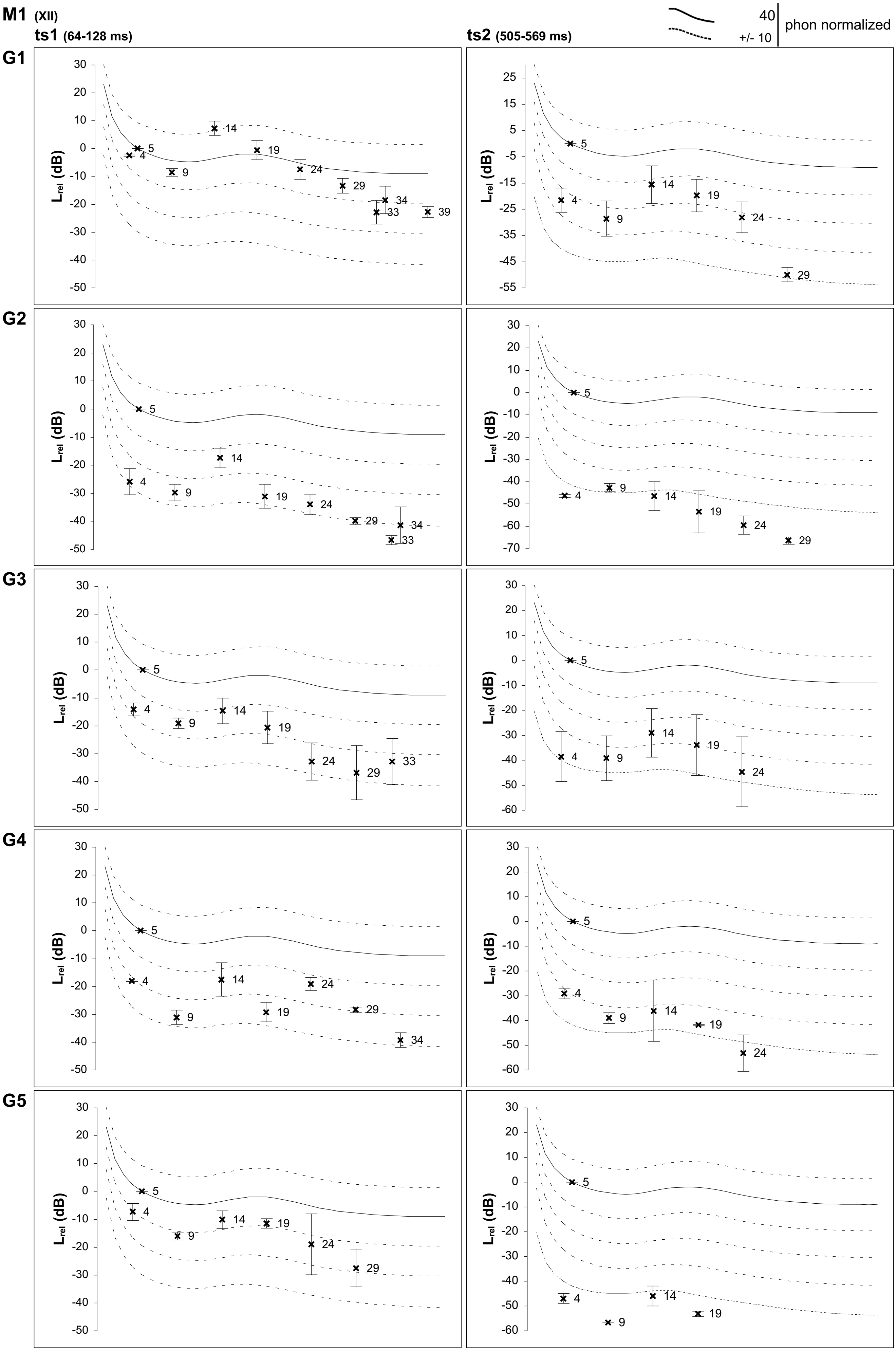
G1 G2 G3 G4 G5




IV
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_{rel} (dB)

IV

M1 (XII)



ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
L_{rel} (dB)

IV

M2 **(Sound hole)**

ts1 **(64-128 ms)** **ts2** **(505-569 ms)**

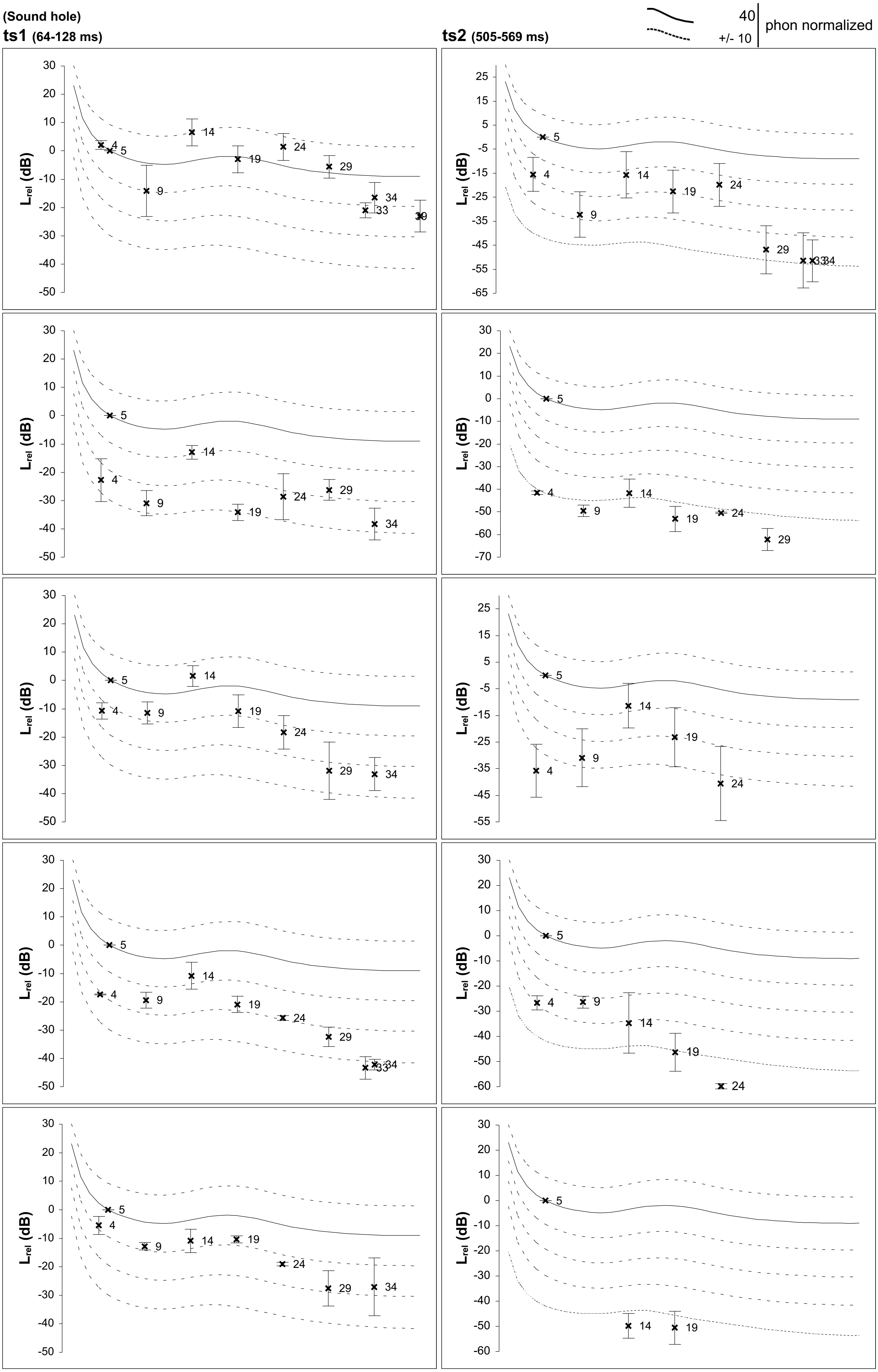
G1

G2

G3

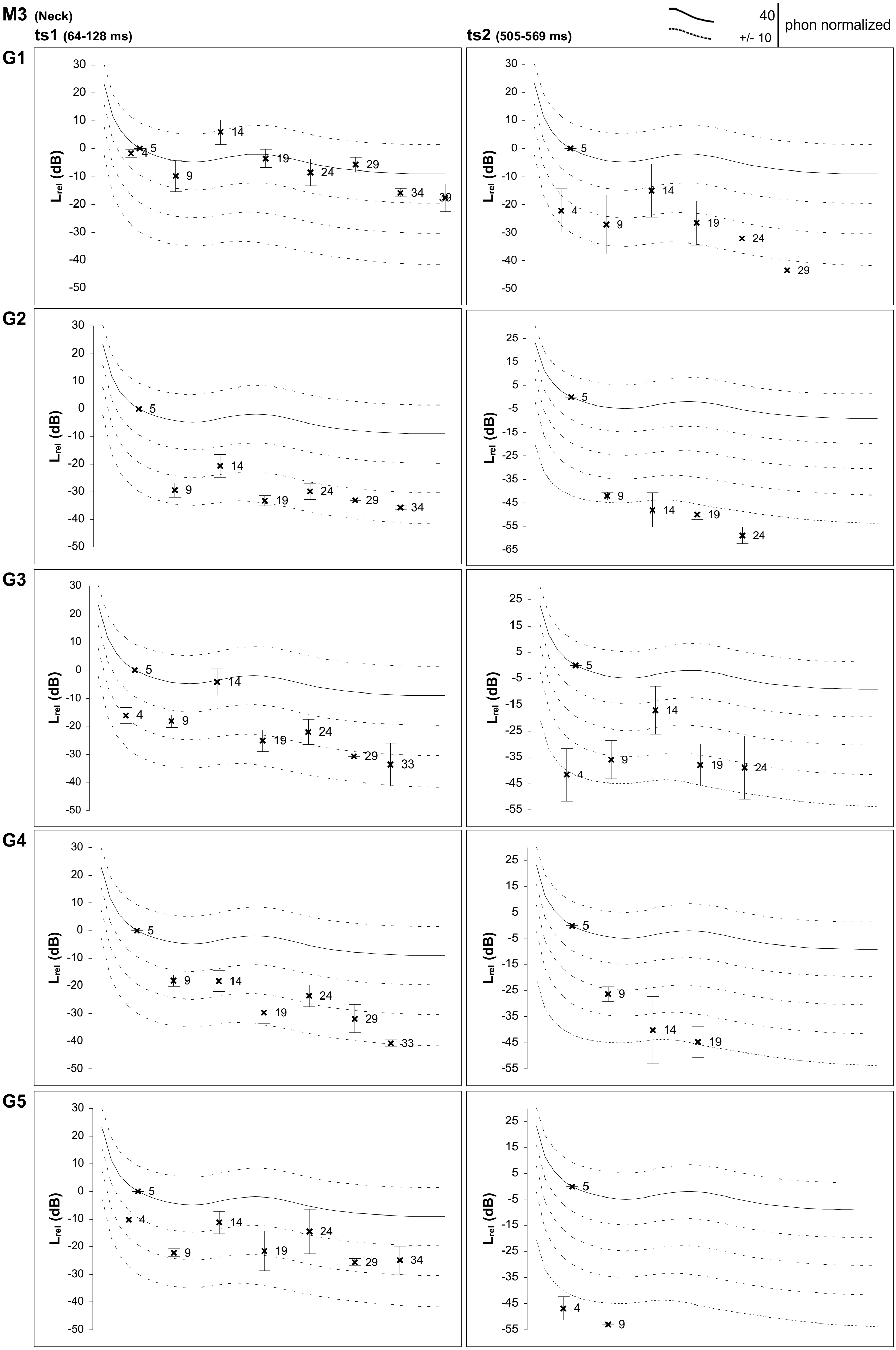
G4

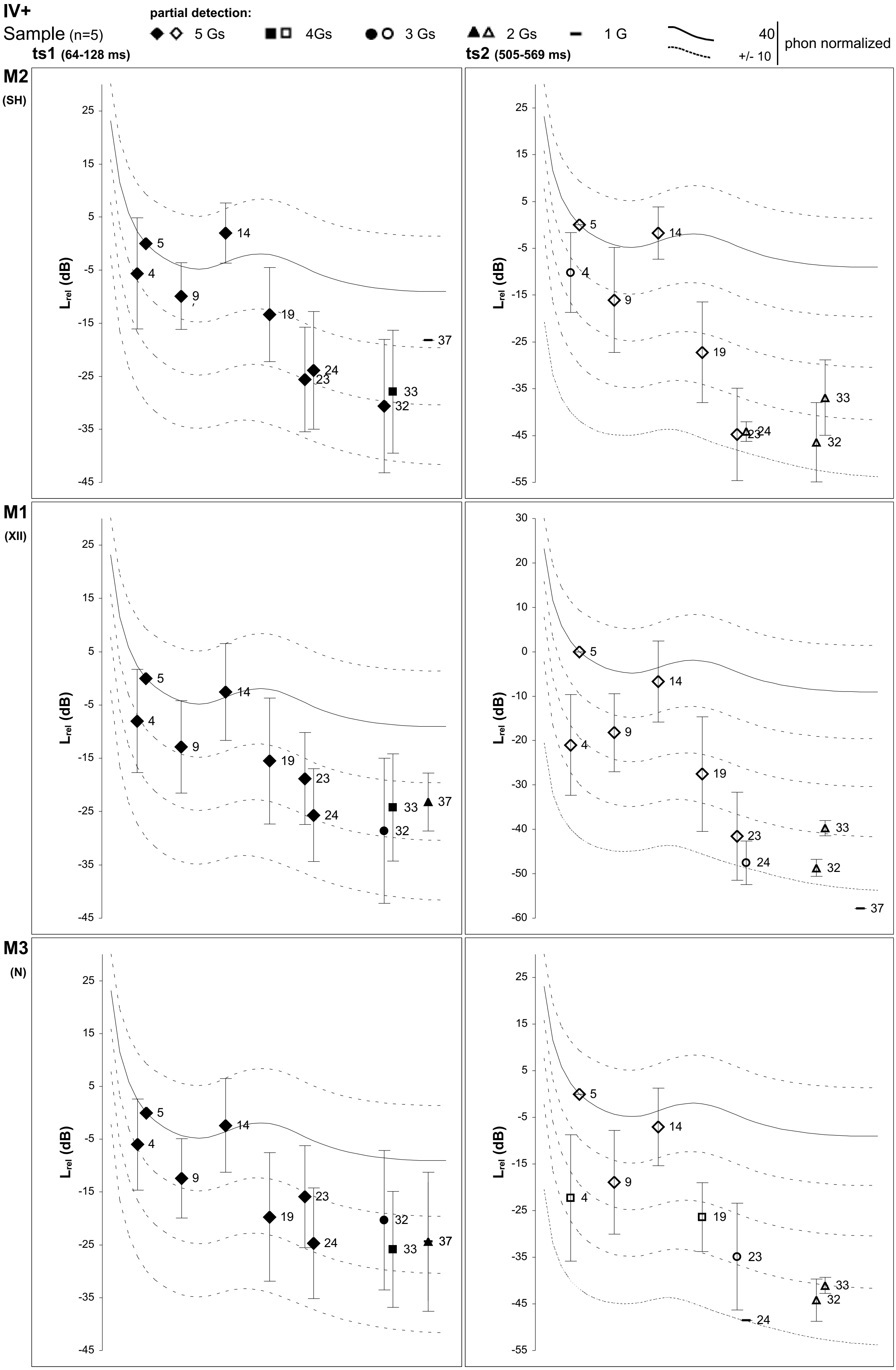
G5



IV

M3 (Neck)


ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
Lrel (dB)


IV+
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_{rel} (dB)

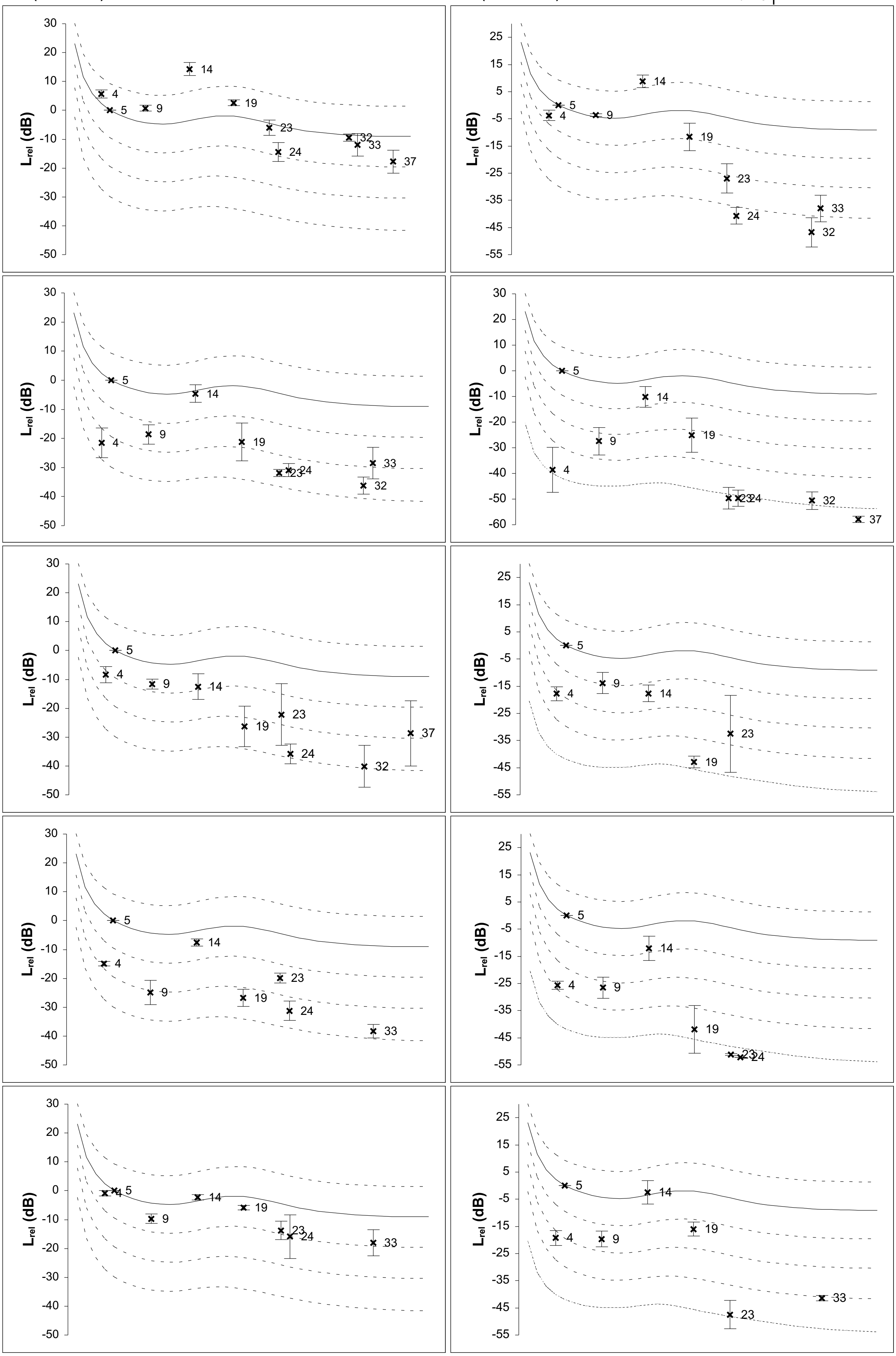
IV+

M1 (XII)

ts1 (64-128 ms) **ts2** (505-569 ms)

40 | phon normalized
+/- 10

G1
G2
G3
G4
G5



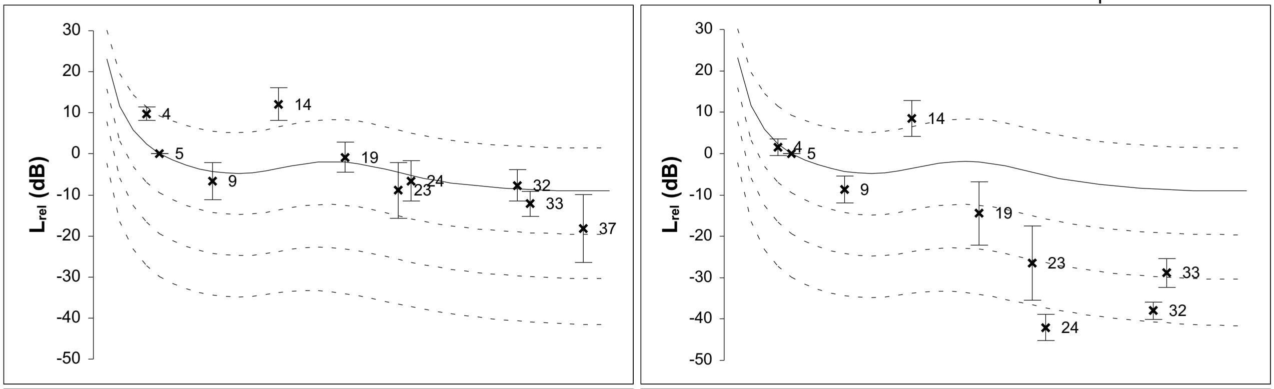
IV+

M2 (Sound hole)

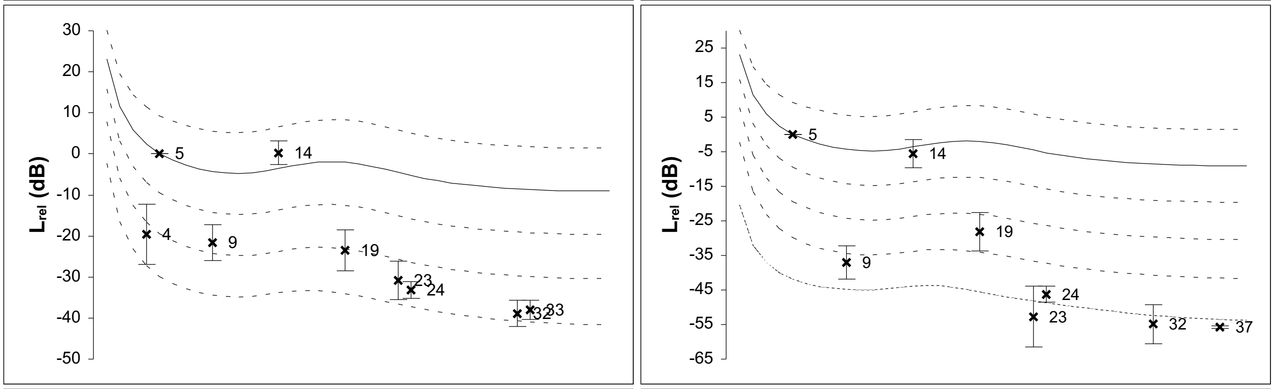
ts1 (64-128 ms) **ts2** (505-569 ms)

40 / +/- 10 | phon normalized

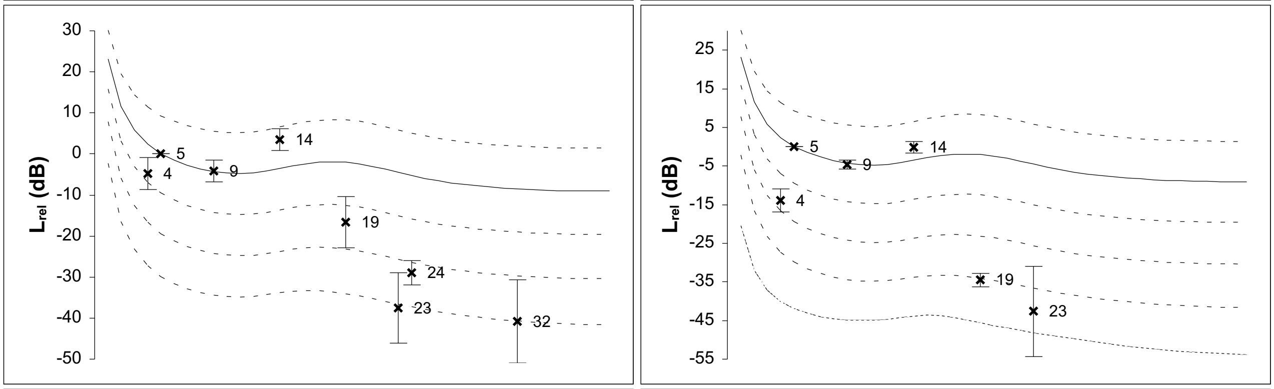
G1



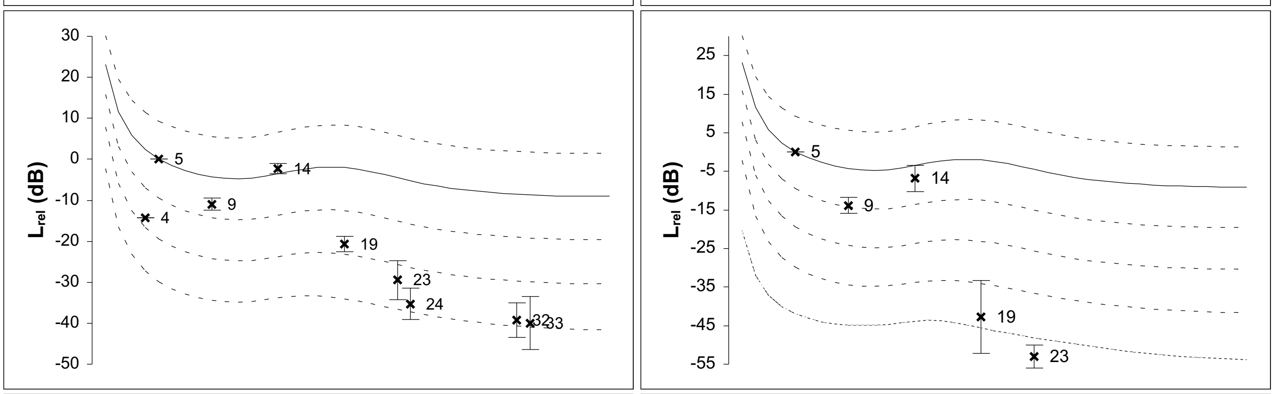
G2



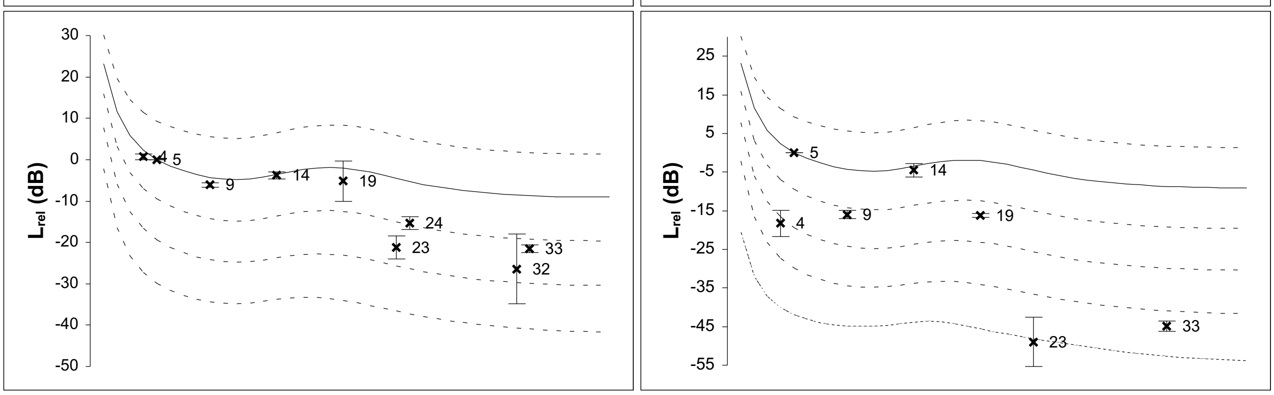
G3



G4



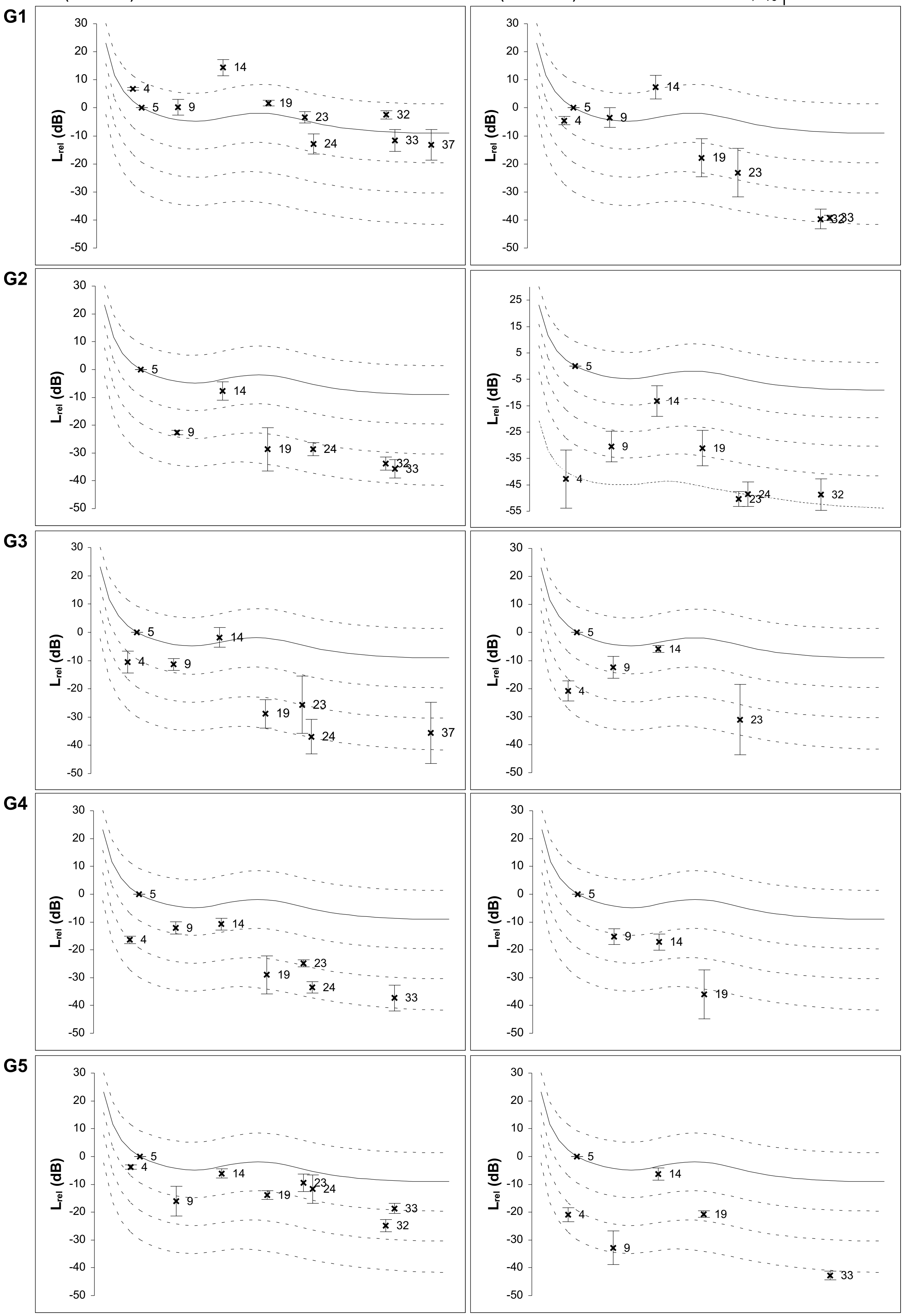
G5

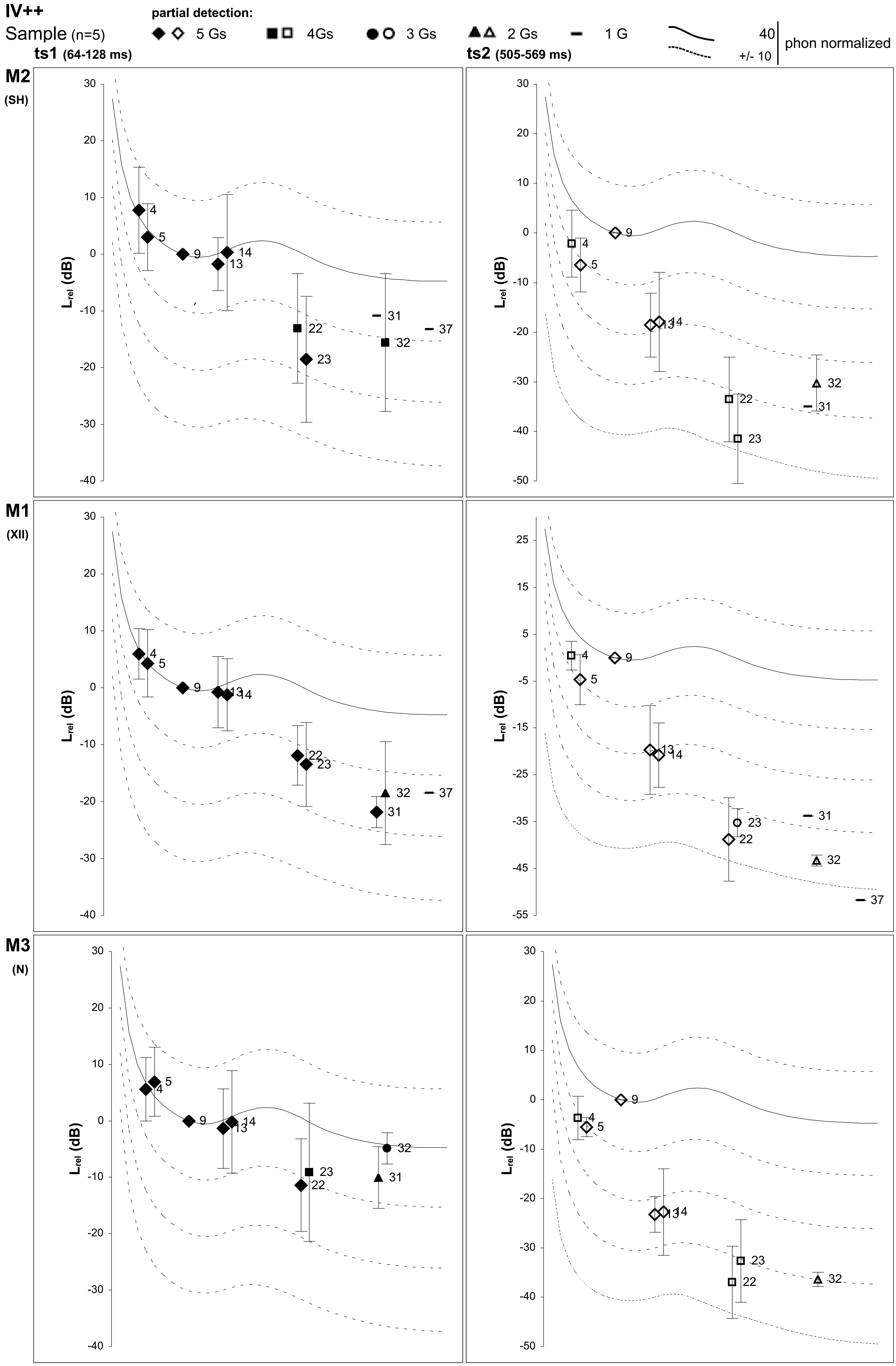


IV+
M3 (Neck)

ts1 (64-128 ms) **ts2** (505-569 ms)

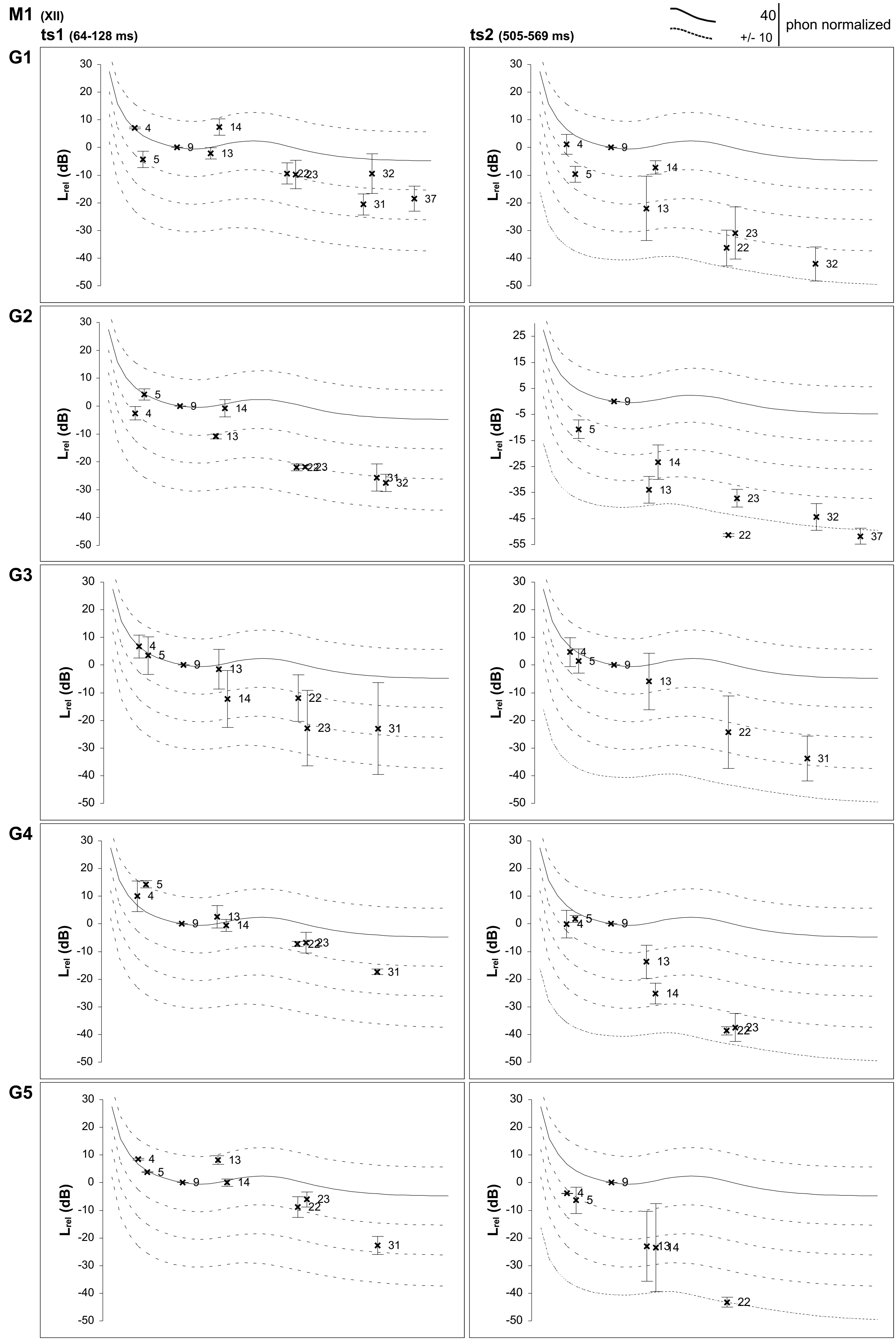
40 / +/- 10 phon normalized




IV++
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_{rel} (dB)

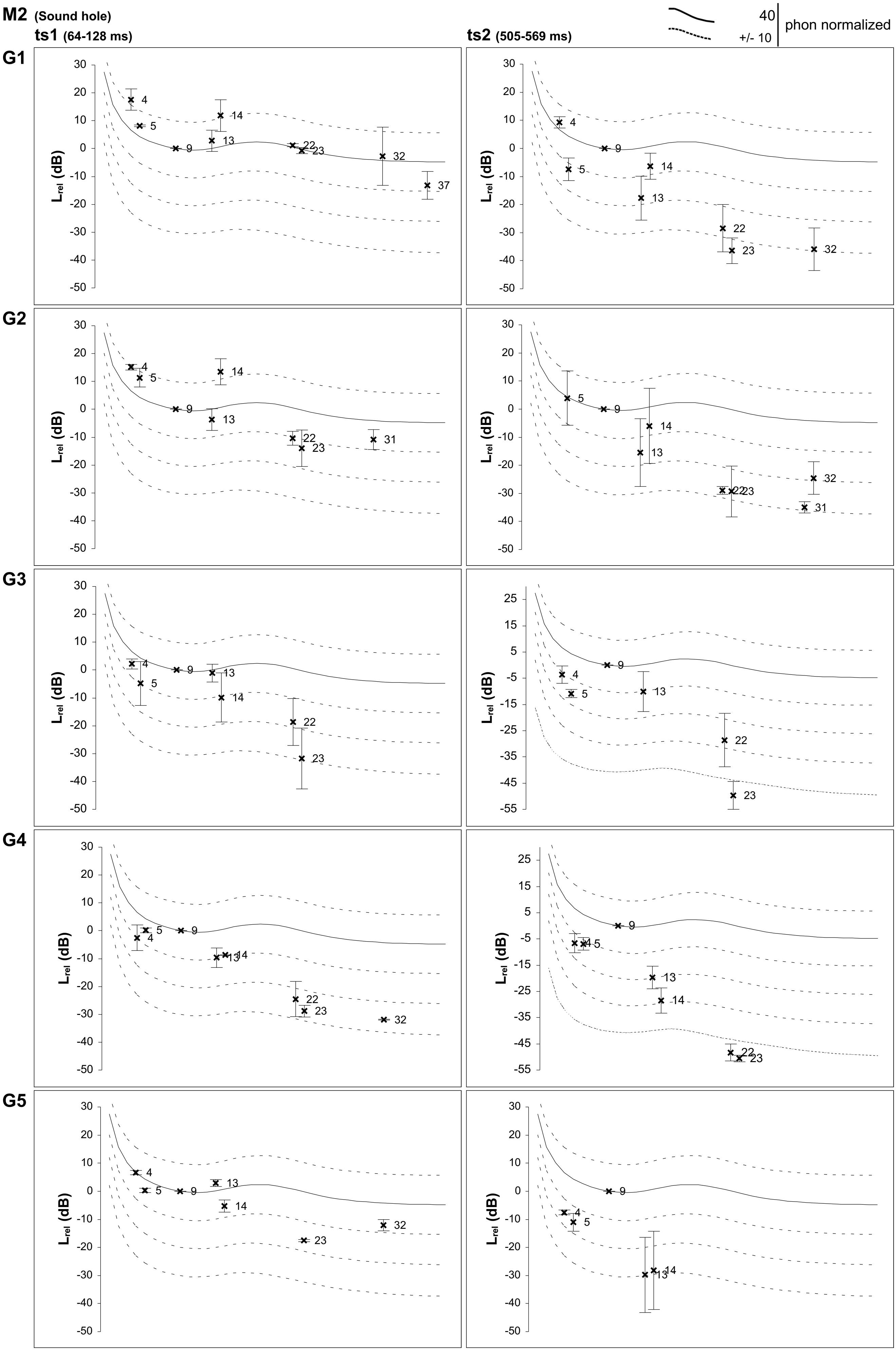
IV++

M1 (XII)


40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
G1
G2
G3
G4
G5
Lrel (dB)

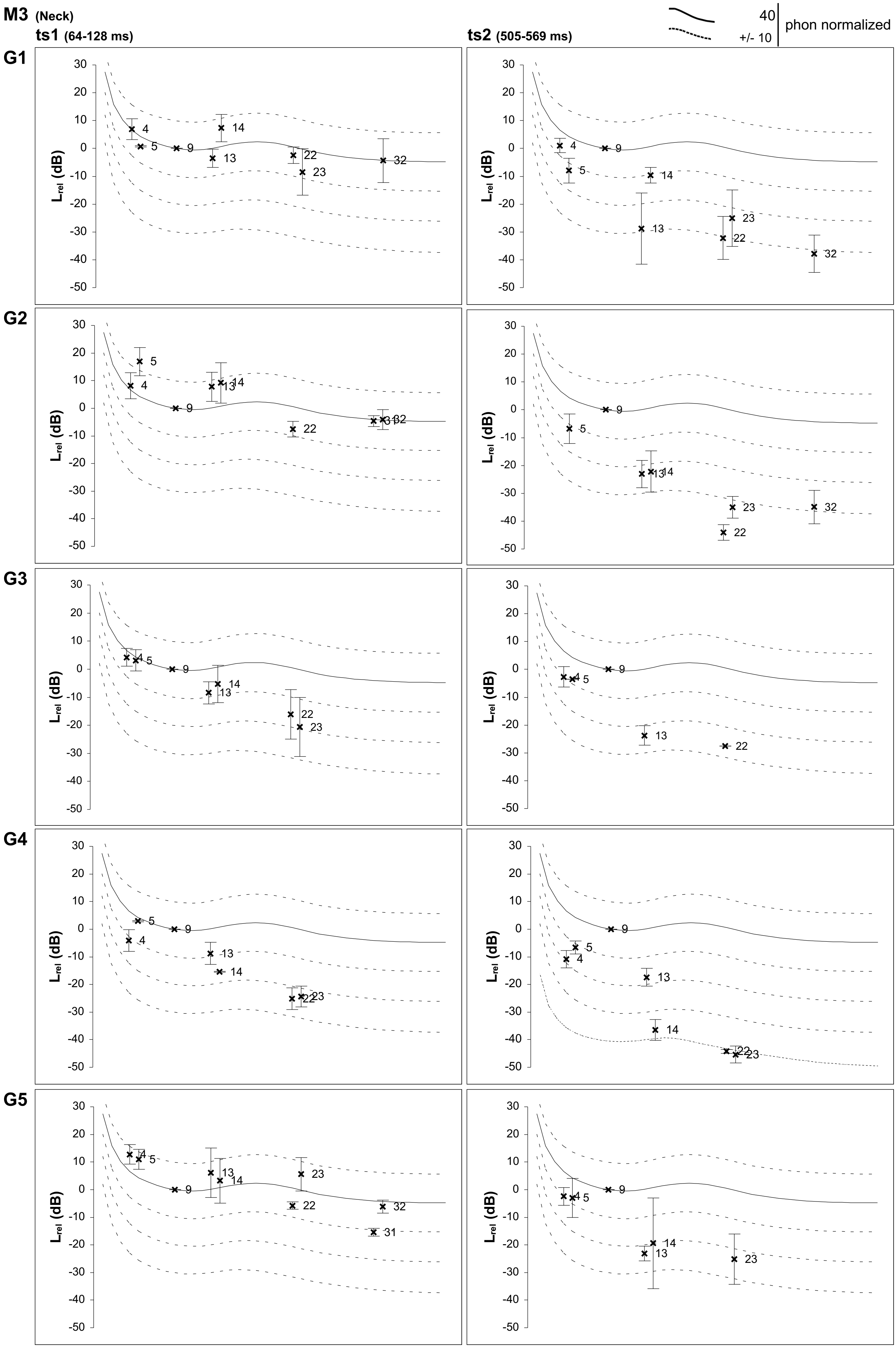
IV++

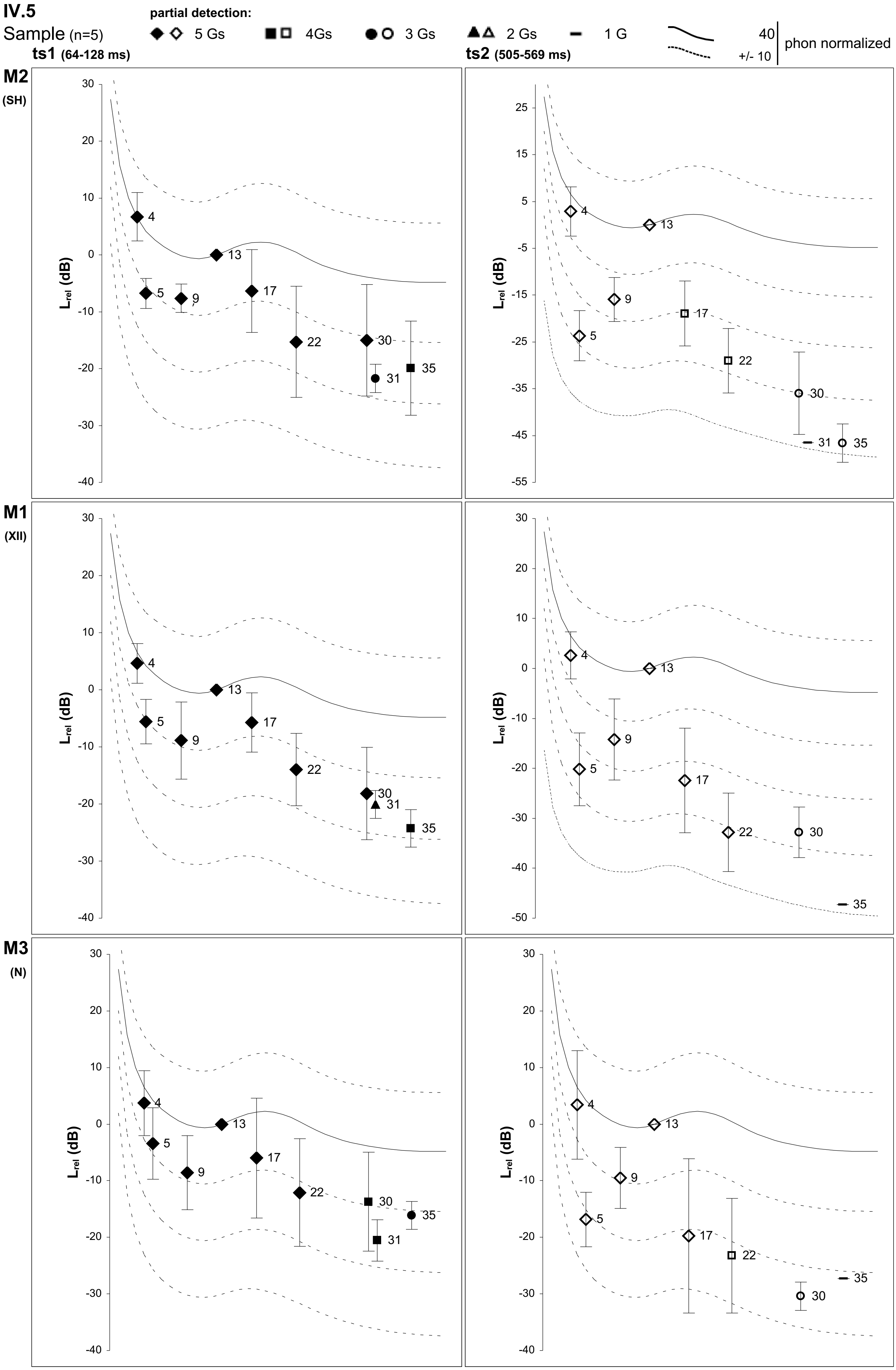
M2 **(Sound hole)**



IV++

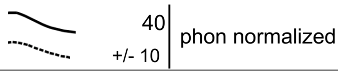
M3 (Neck)


ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
L_rel (dB)
30
20
10
0
-10
-20
-30
-40
-50
4
5
9
13
14
22
23
31
32


IV.5
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_rel (dB)
4
5
9
13
17
22
30
31
35

IV.5

M1 (XII)



ts1 (64-128 ms)

ts2 (505-569 ms)

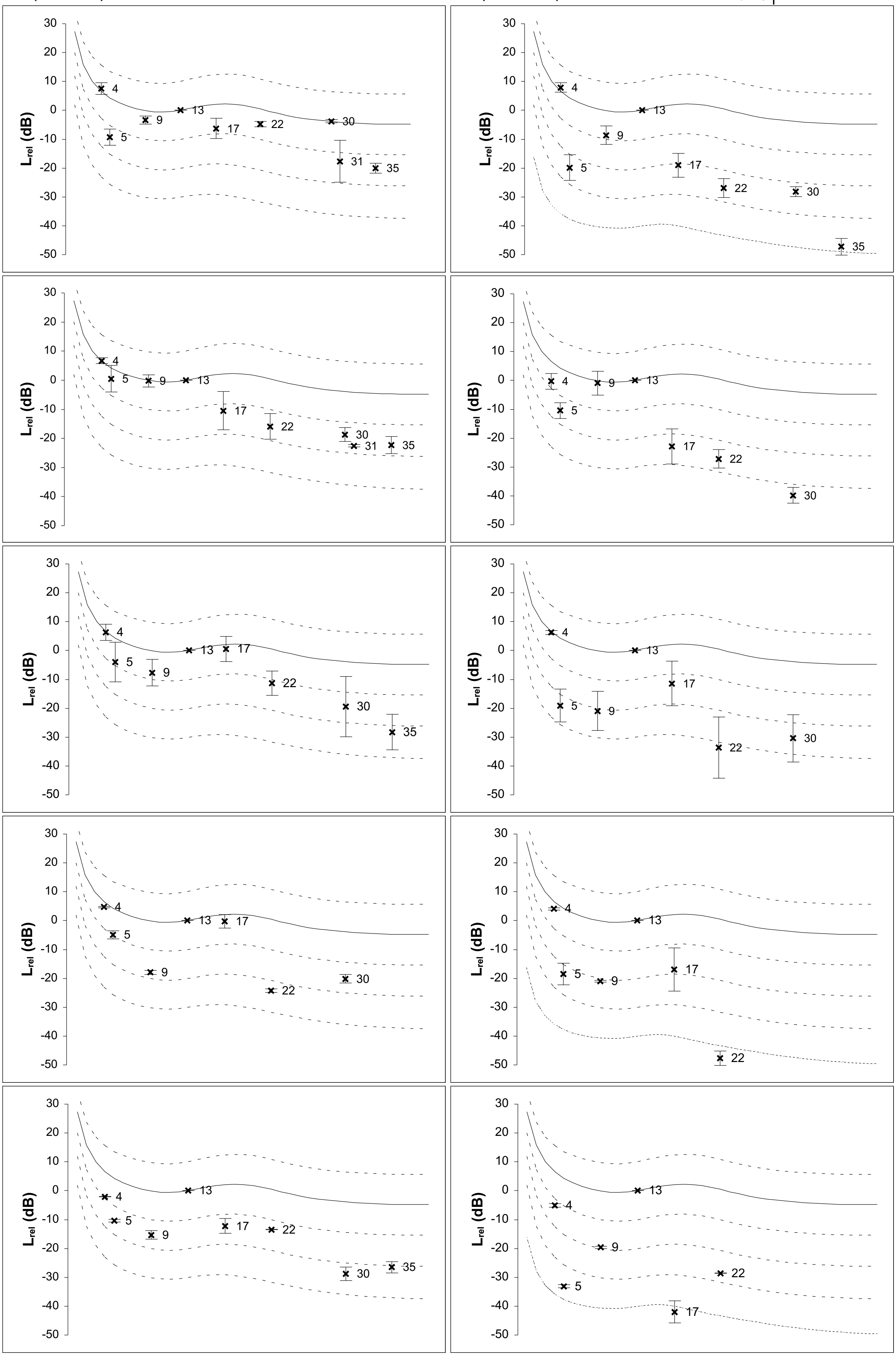
G1

G2

G3

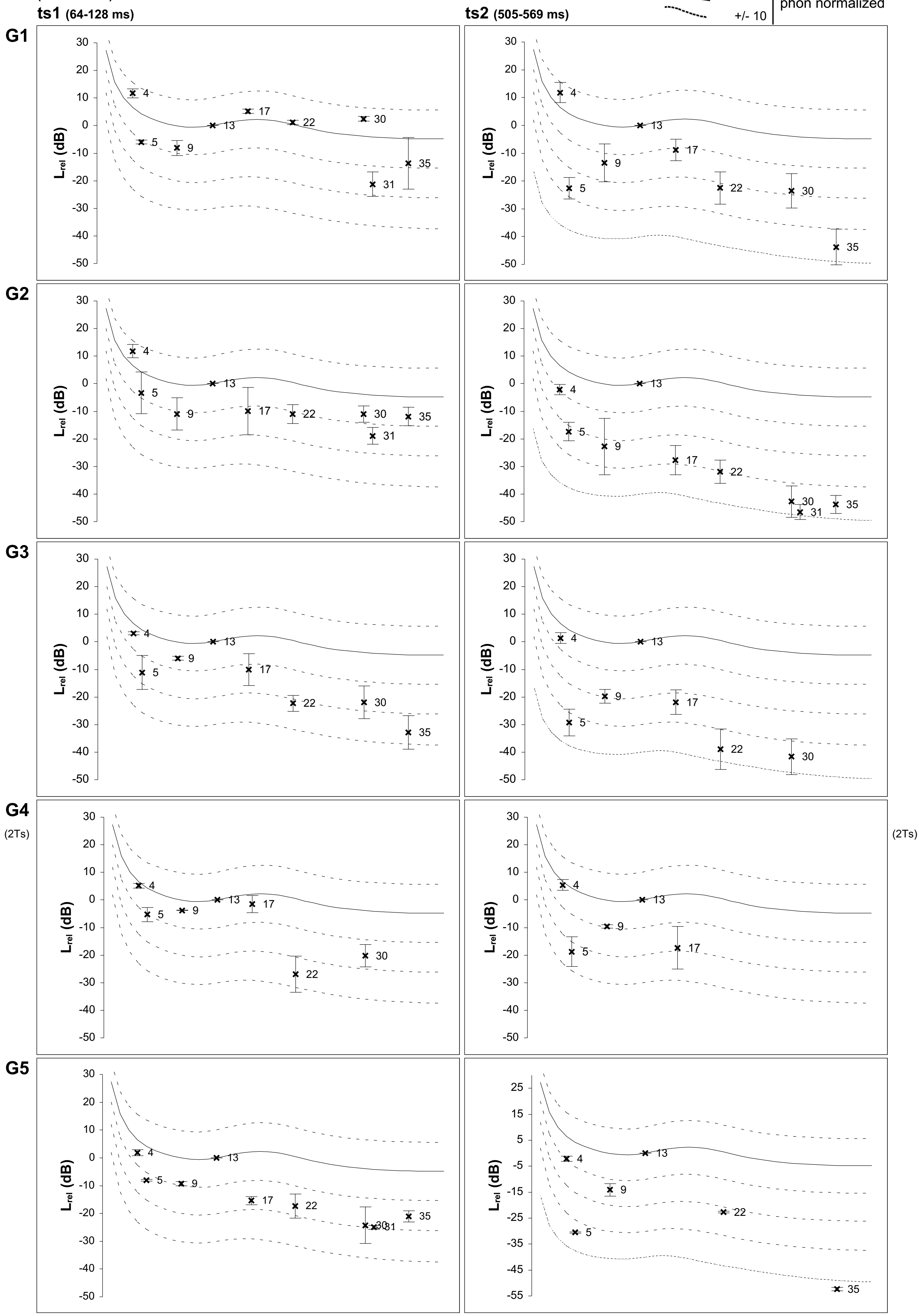
G4 (2Ts)

G5



IV.5

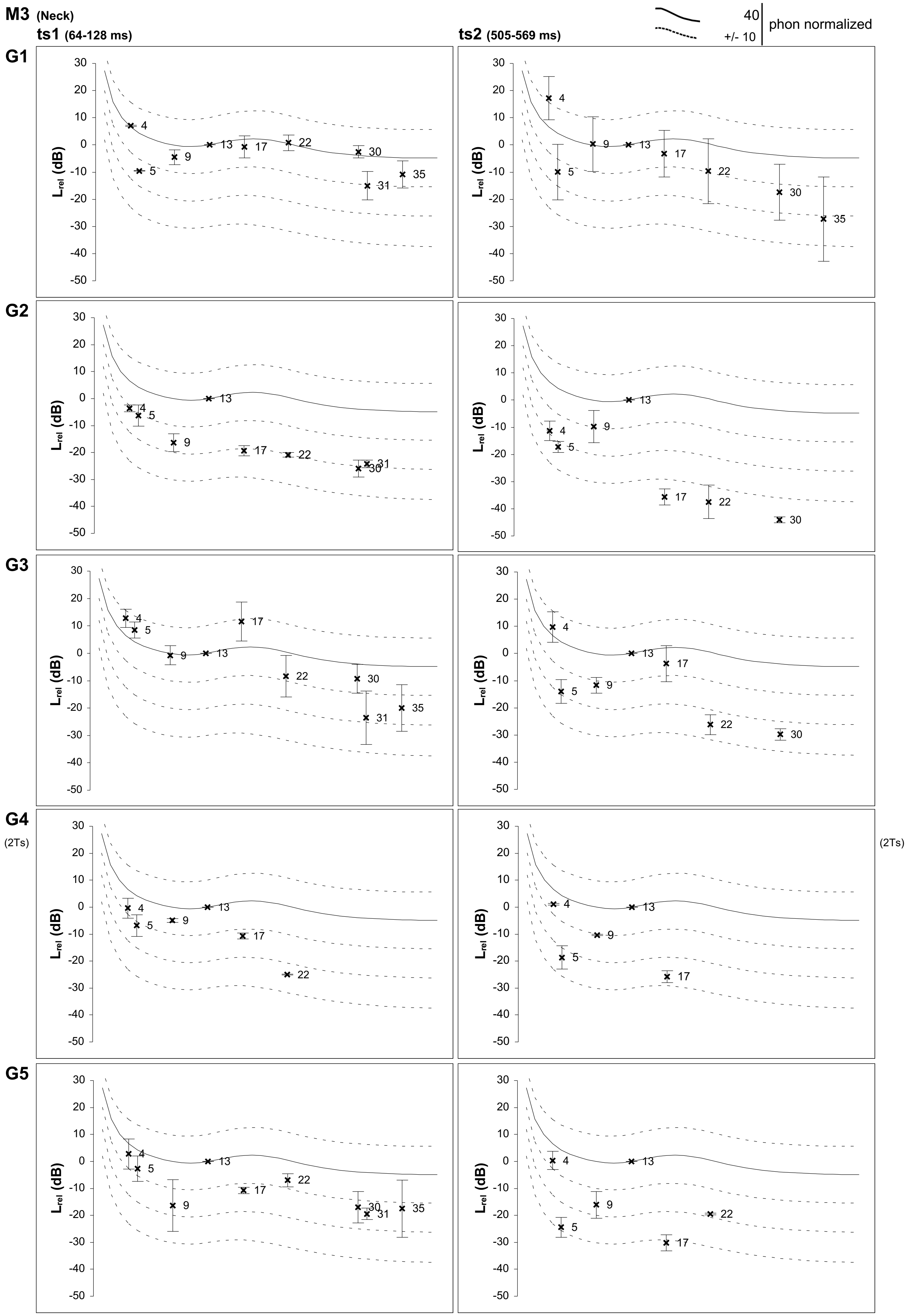
M2 (Sound hole)

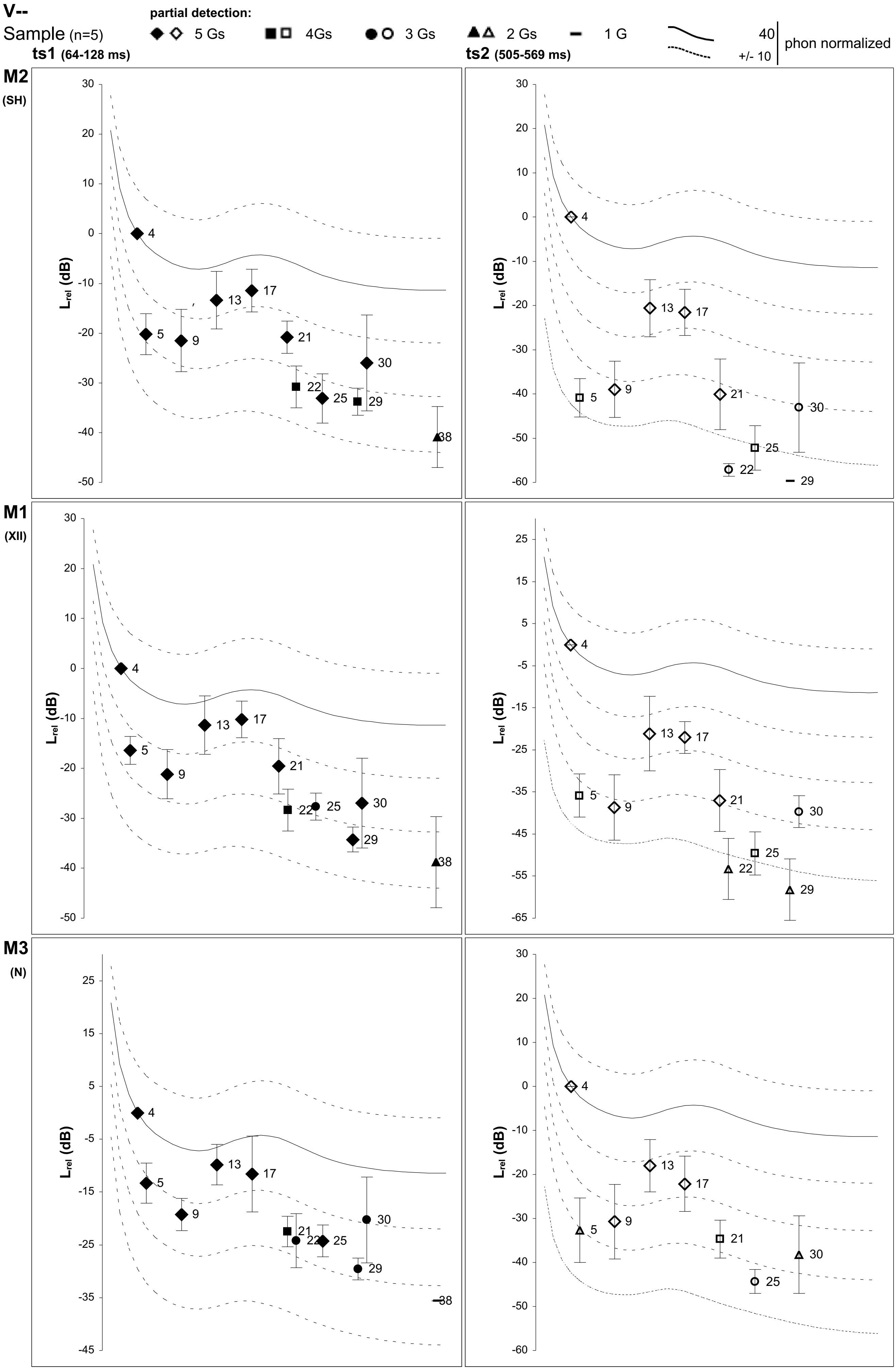


IV.5

M3 (Neck)

ts1 (64-128 ms) **ts2** (505-569 ms)





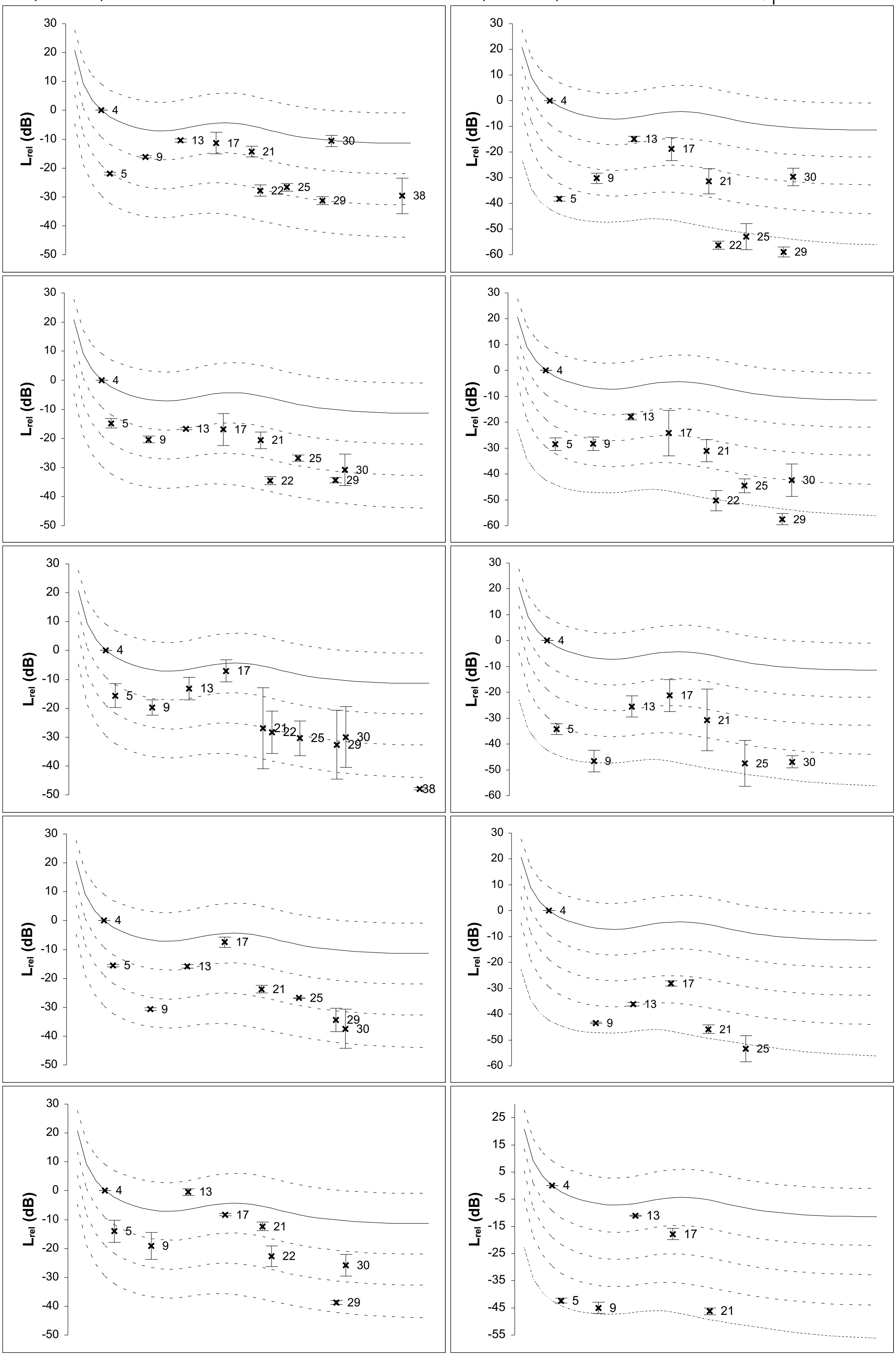
V--
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_rel (dB)

V--
M1 (XII)

ts1 (64-128 ms) **ts2** (505-569 ms)

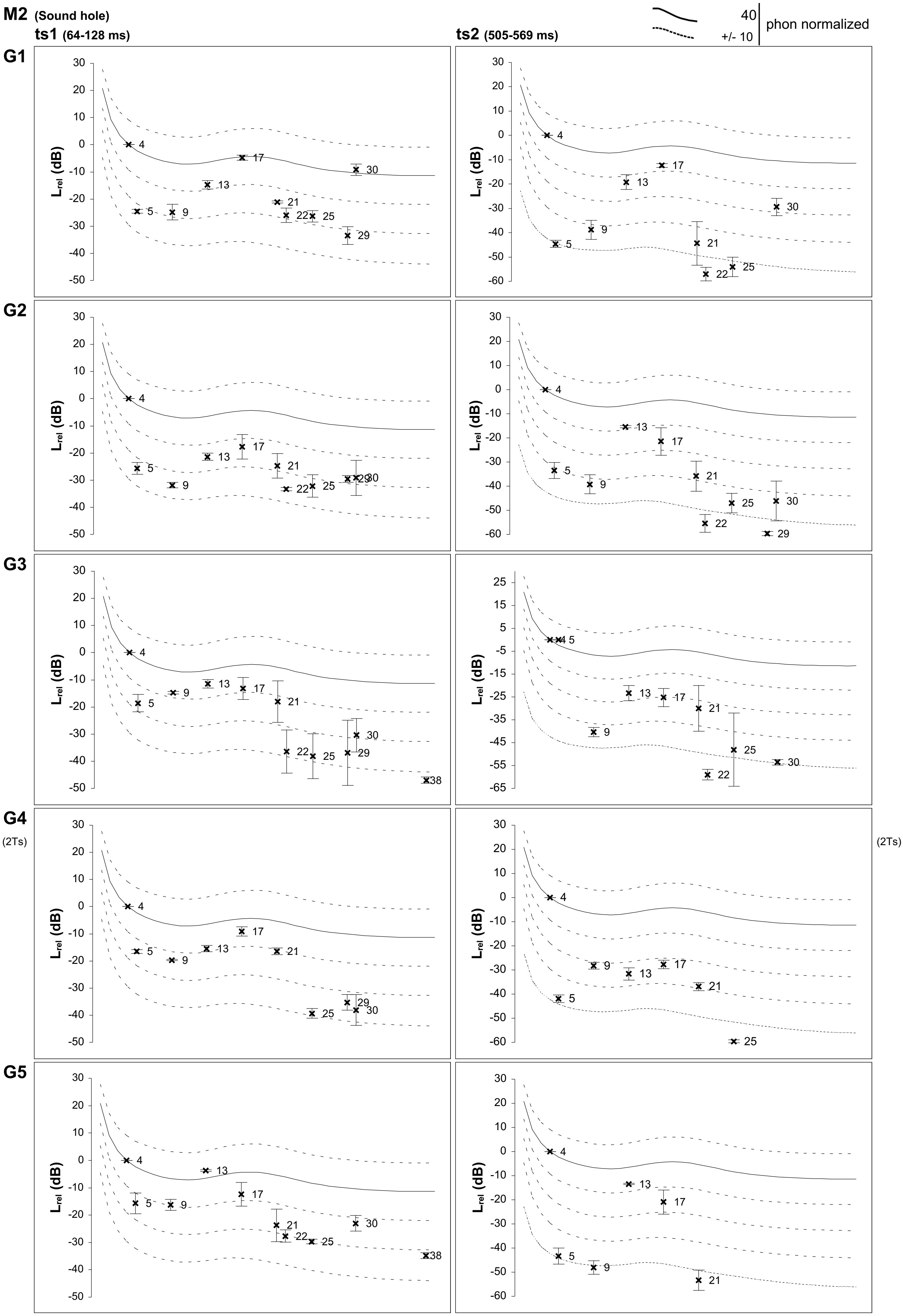
40 | phon normalized
+/- 10

G1
G2
G3
G4 (2Ts)
G5



V--

M2 (Sound hole)



V--

M3 (Neck)

ts1 (64-128 ms) **ts2** (505-569 ms)

40 — phon normalized

+/- 10

G1

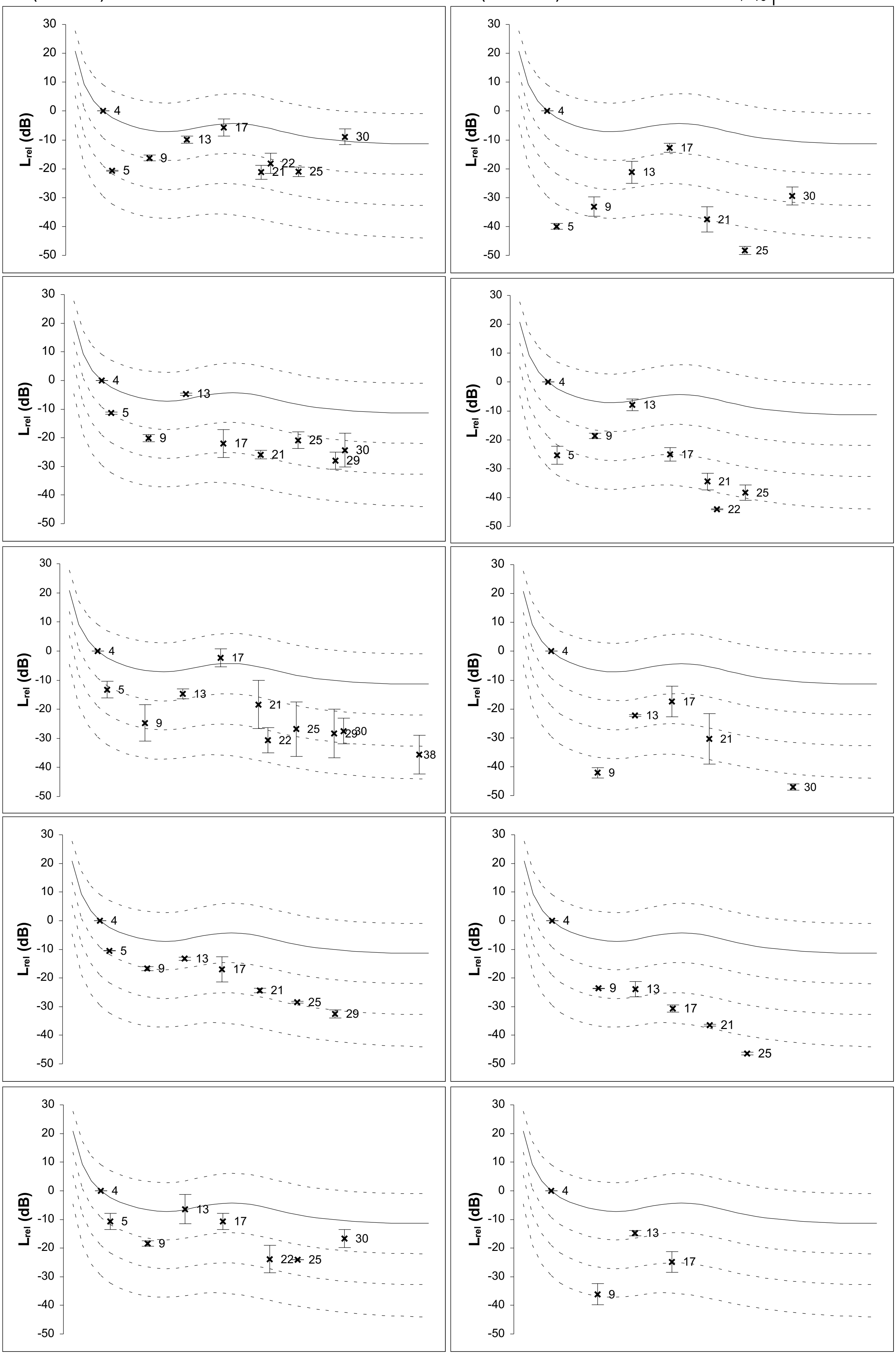
G2

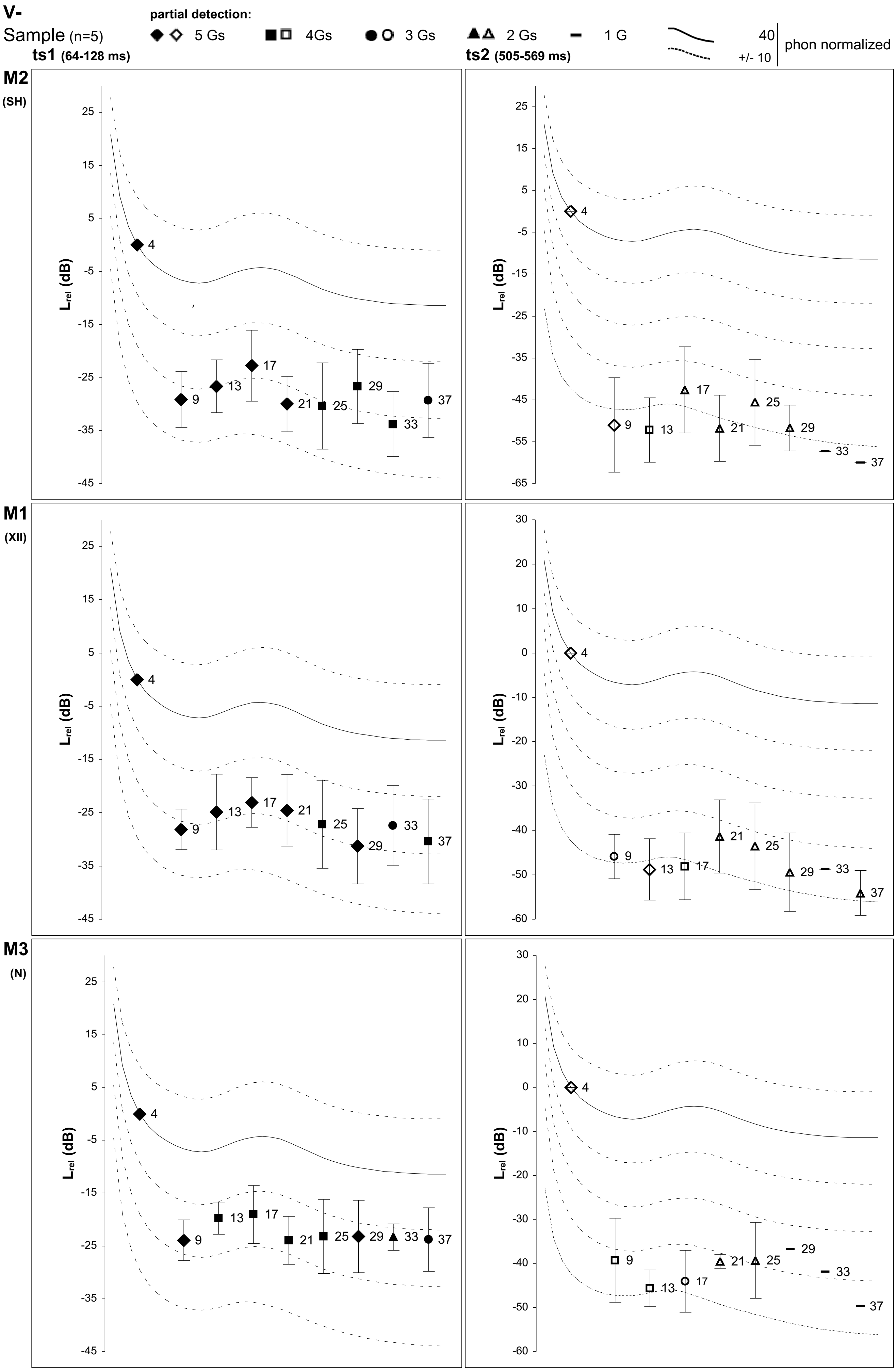
G3

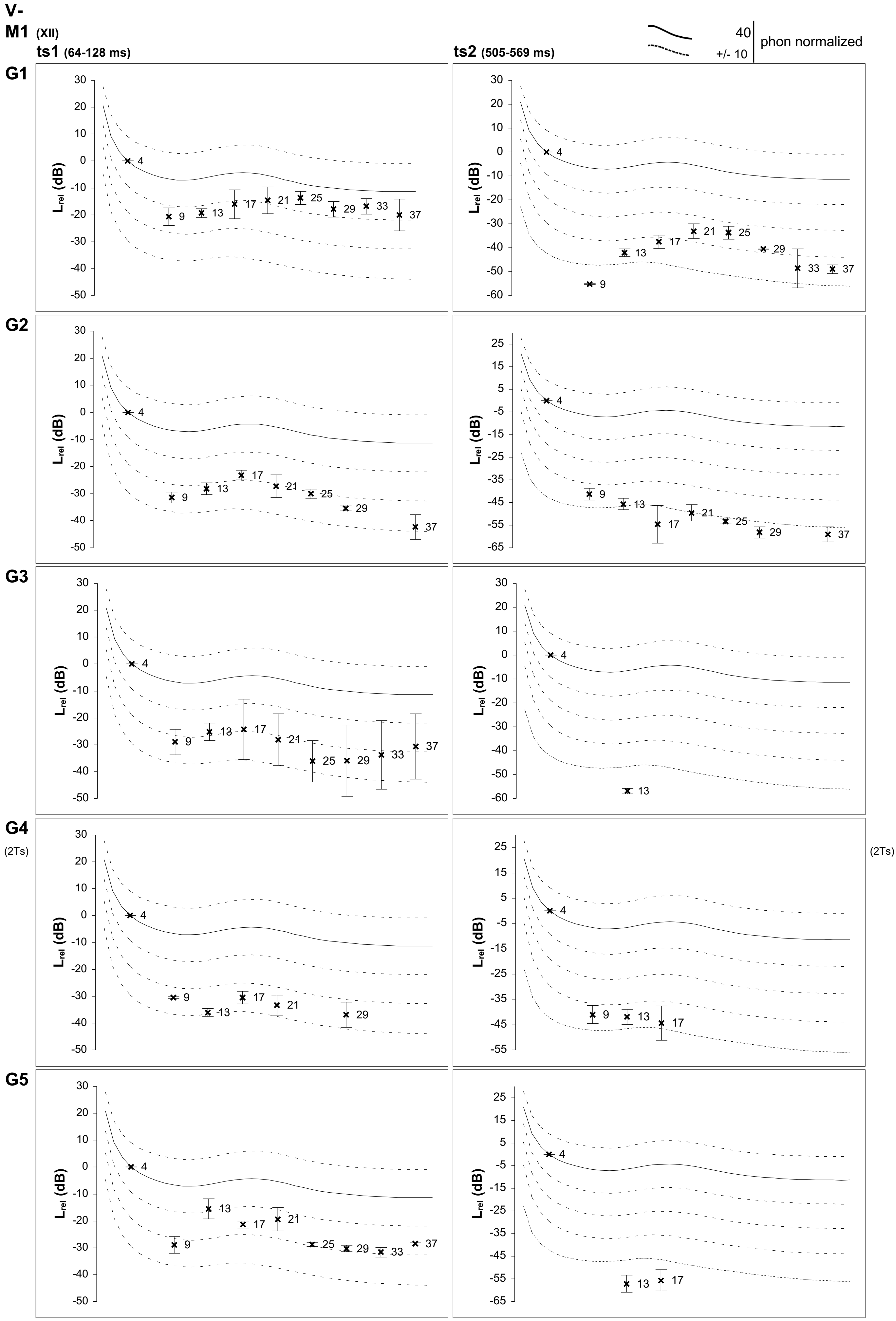
G4

(2Ts)

G5




V-
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_{rel} (dB)


V-
M1 (XII)
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
(2Ts)
G5
L_rel (dB)

V-
M2 **(Sound hole)**

ts1 **(64-128 ms)** **ts2** **(505-569 ms)**

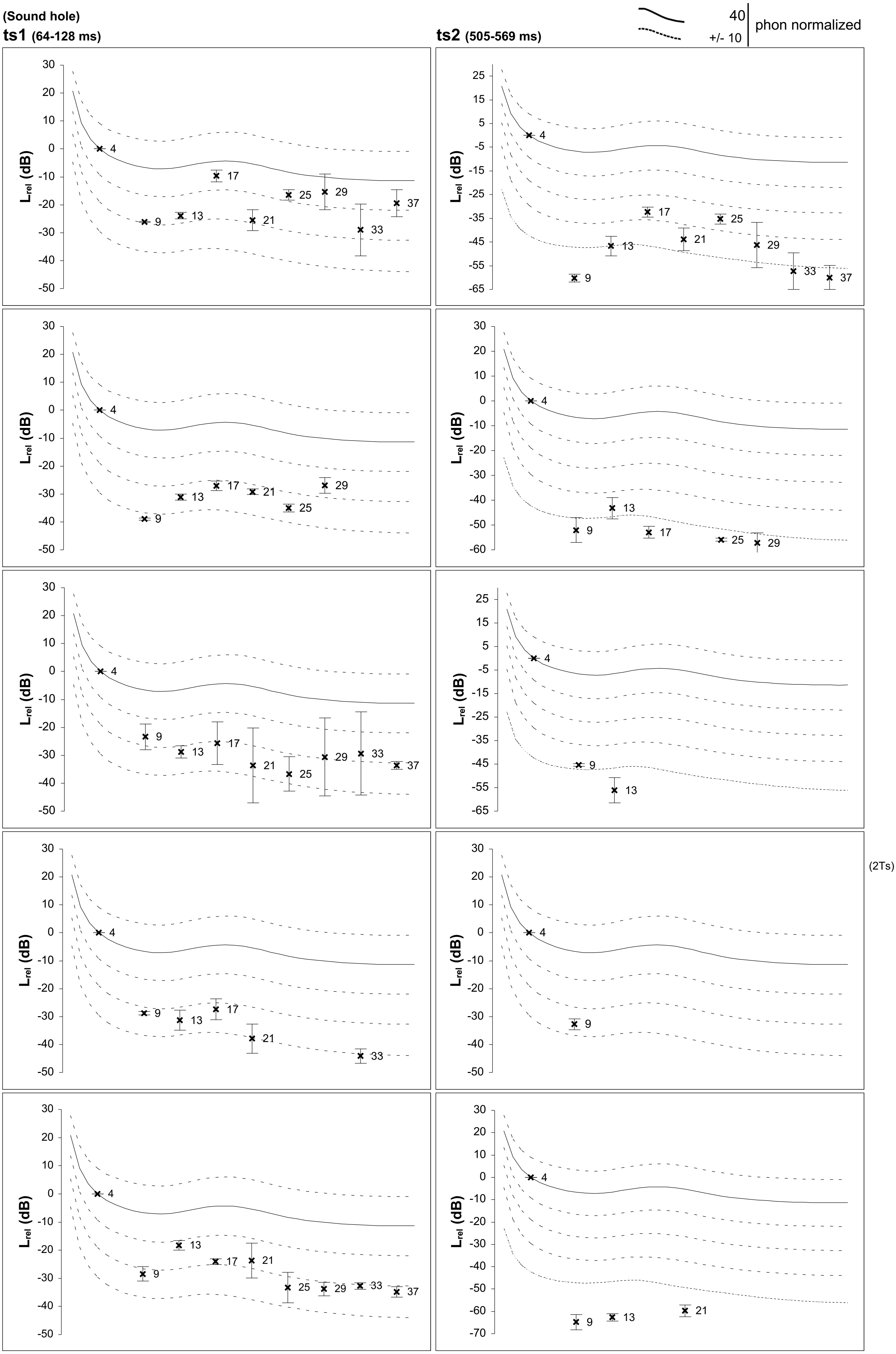
G1

G2

G3

G4
(2Ts)

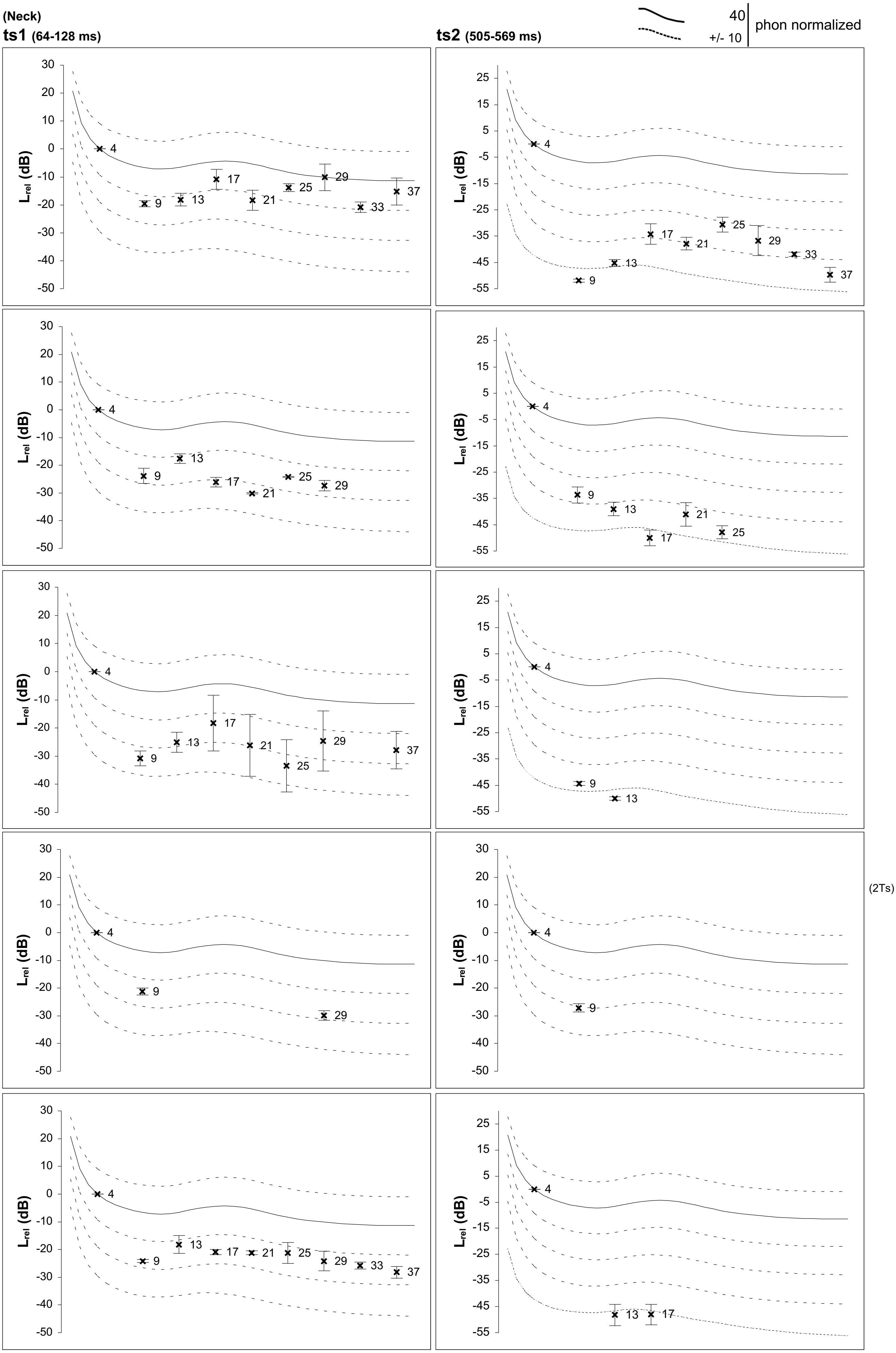
G5

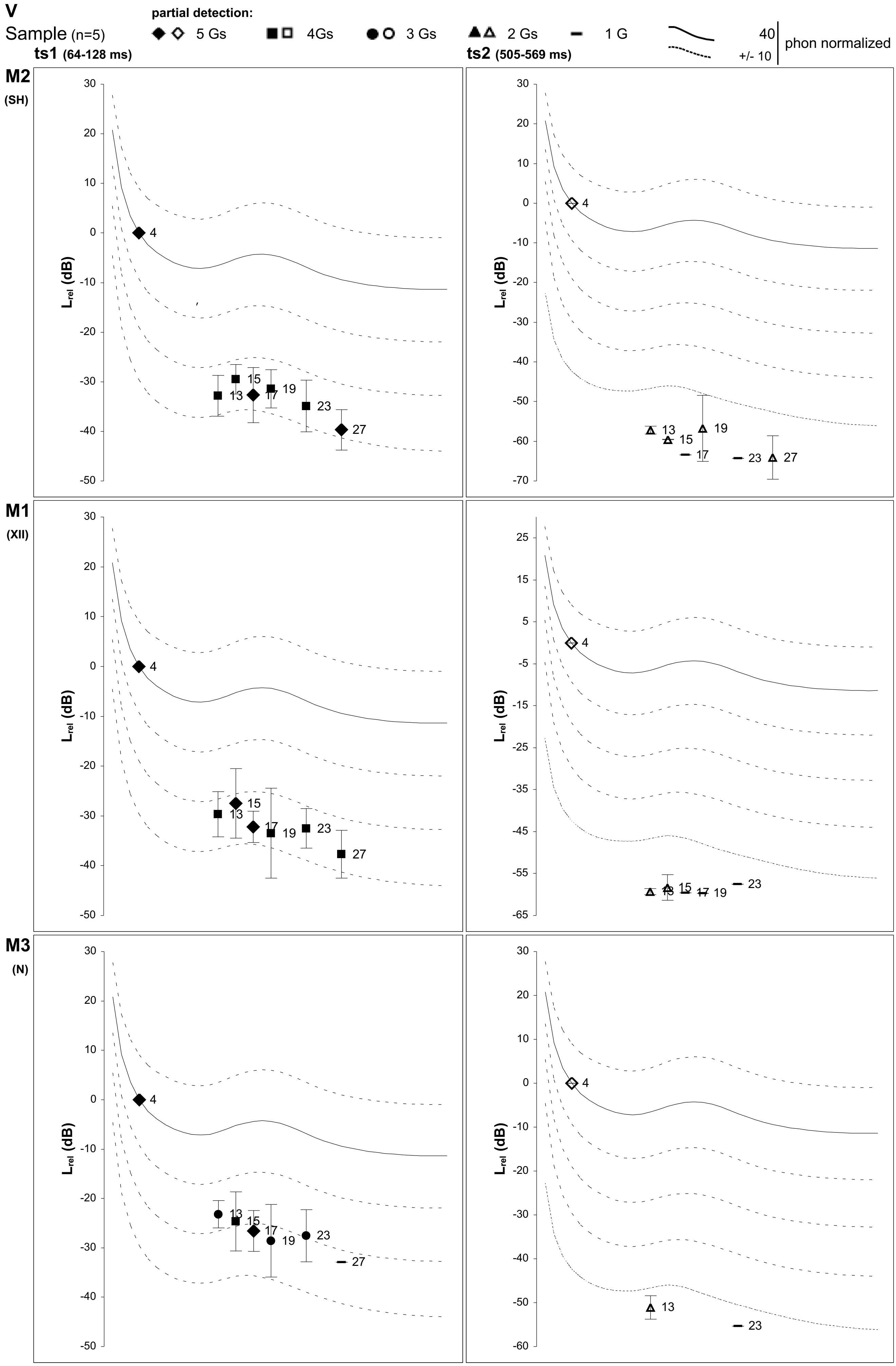


V-
M3 **(Neck)**

ts1 **(64-128 ms)** **ts2** **(505-569 ms)**

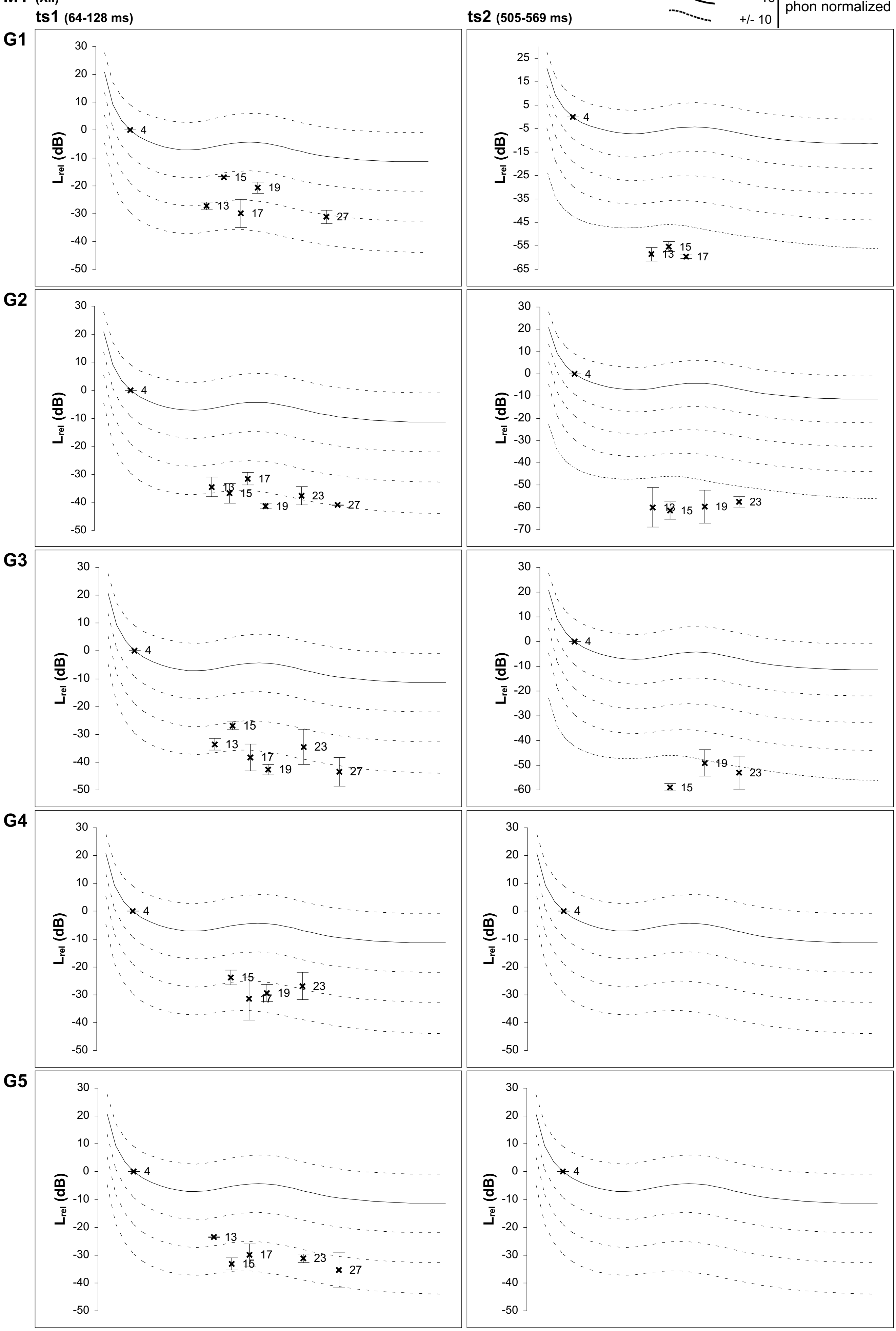
G1
G2
G3
G4
(2Ts)
G5




V
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_rel (dB)
4
13
15
17
19
23
27

V

M1 (XII)



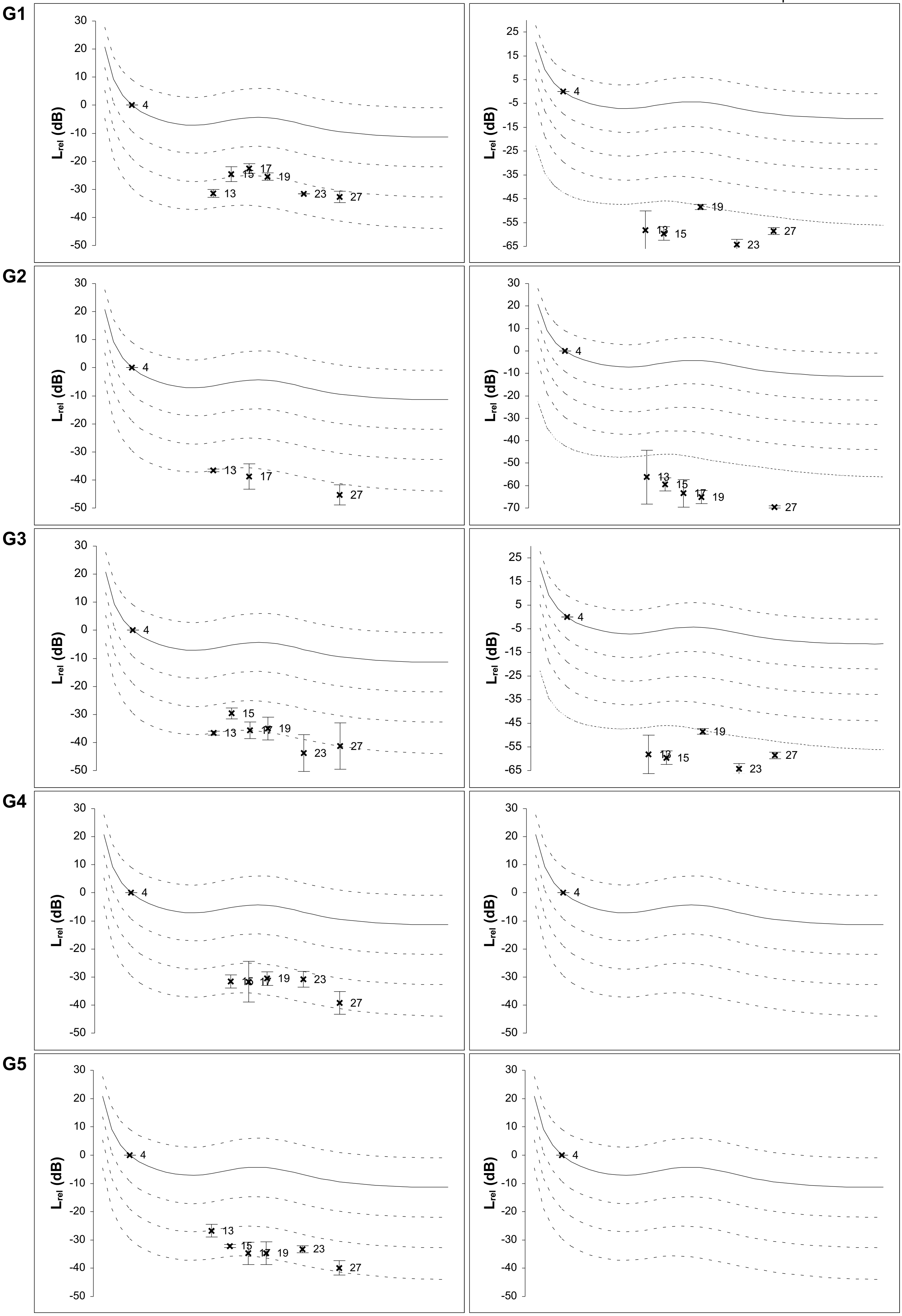
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
L_{rel} (dB)

V

M2 (Sound hole)

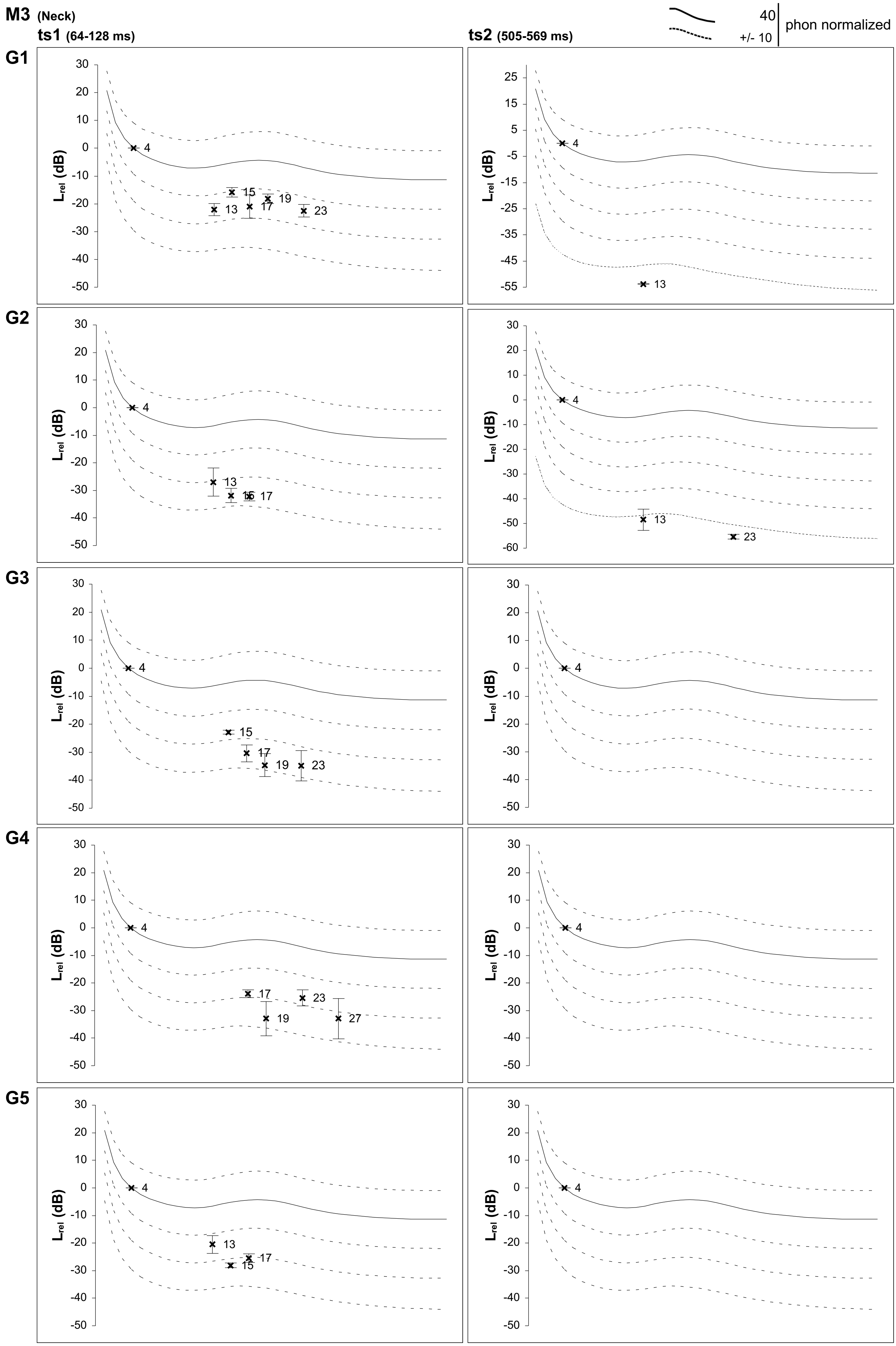
40 | +/- 10 | phon normalized

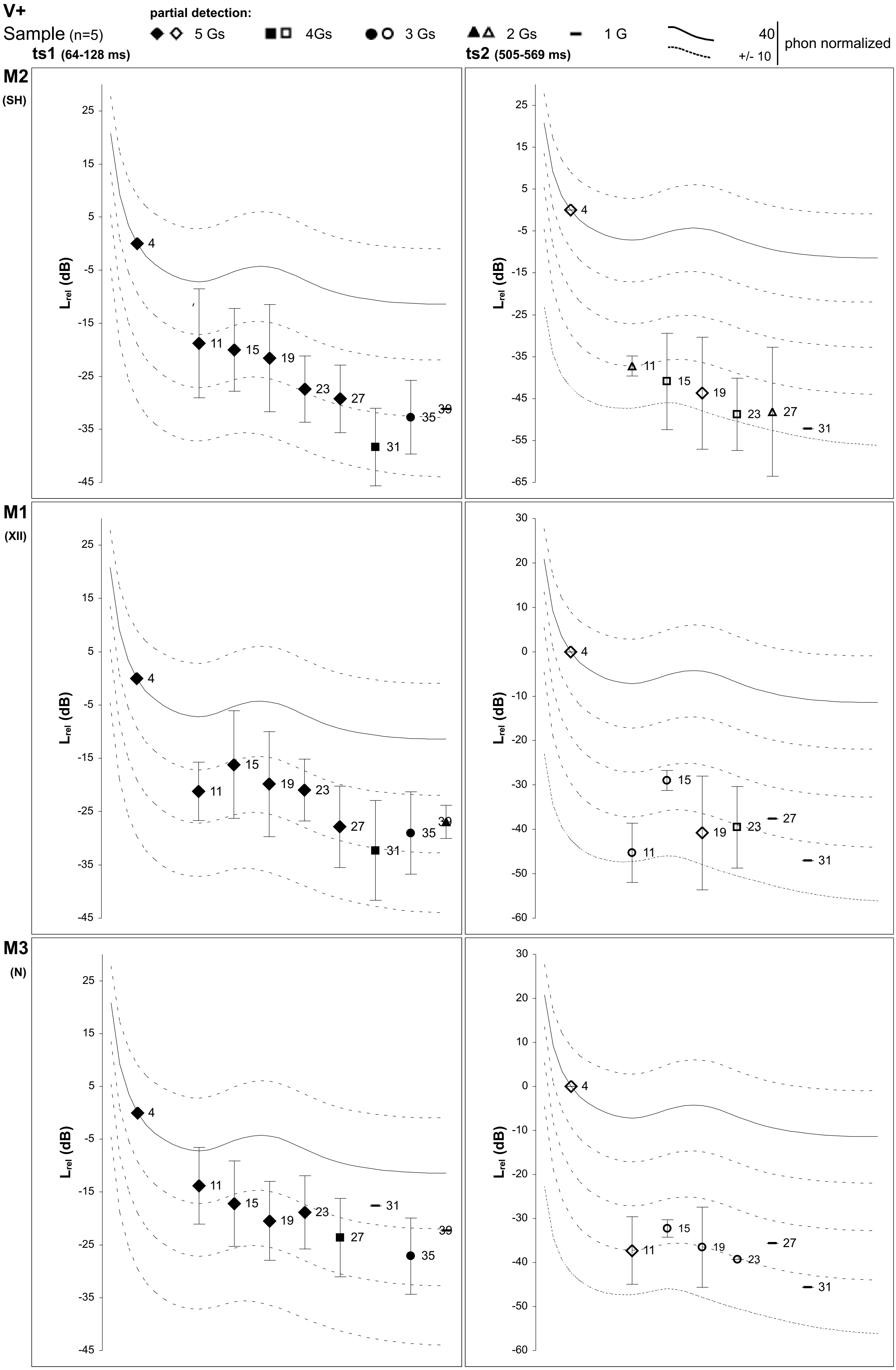
ts1 (64-128 ms) **ts2** (505-569 ms)



V

M3 (Neck)


ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
L_{rel} (dB)
4
13
15
17
19
23
27



V+
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_{rel} (dB)

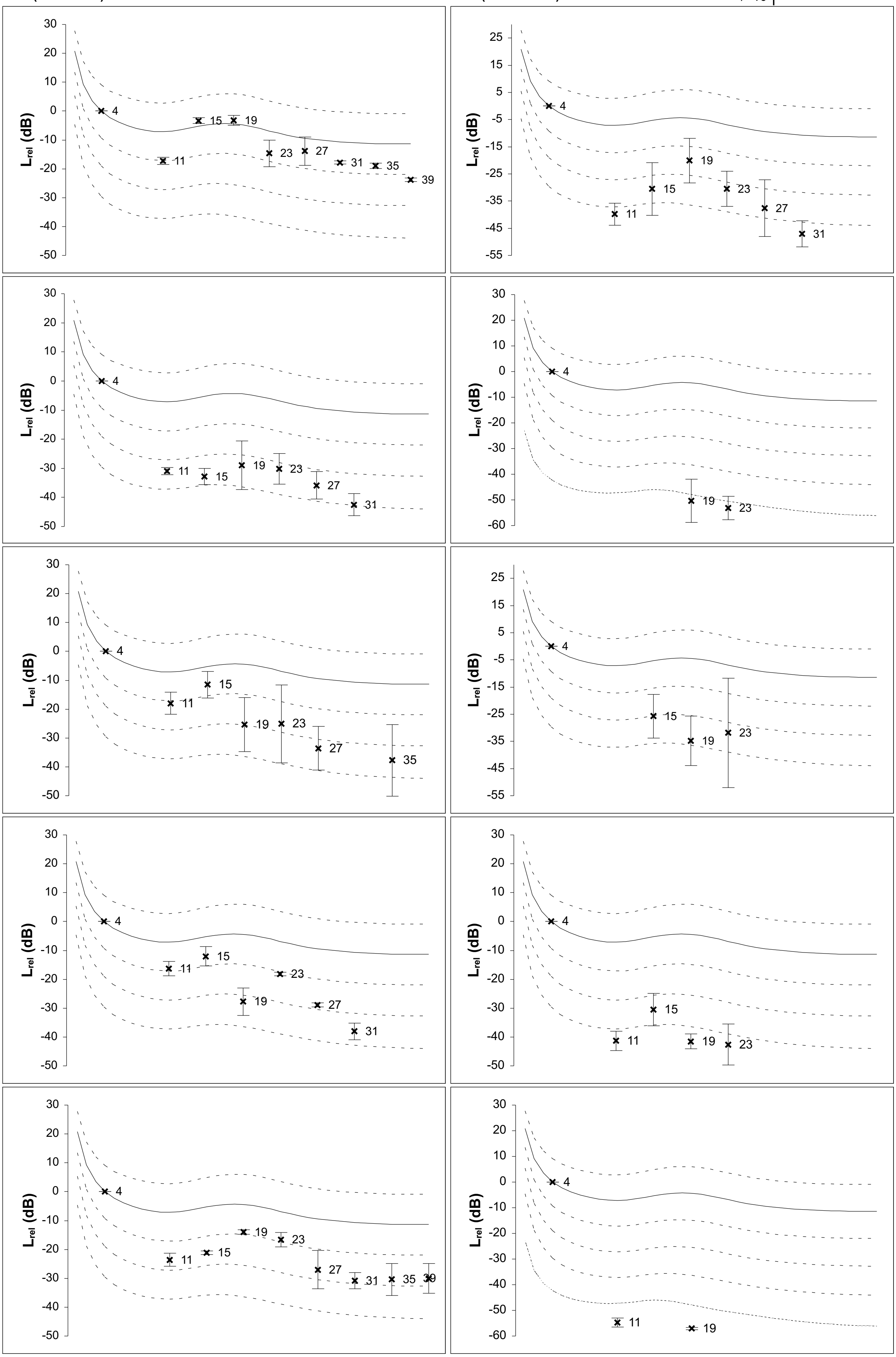
V+

M1 (XII)

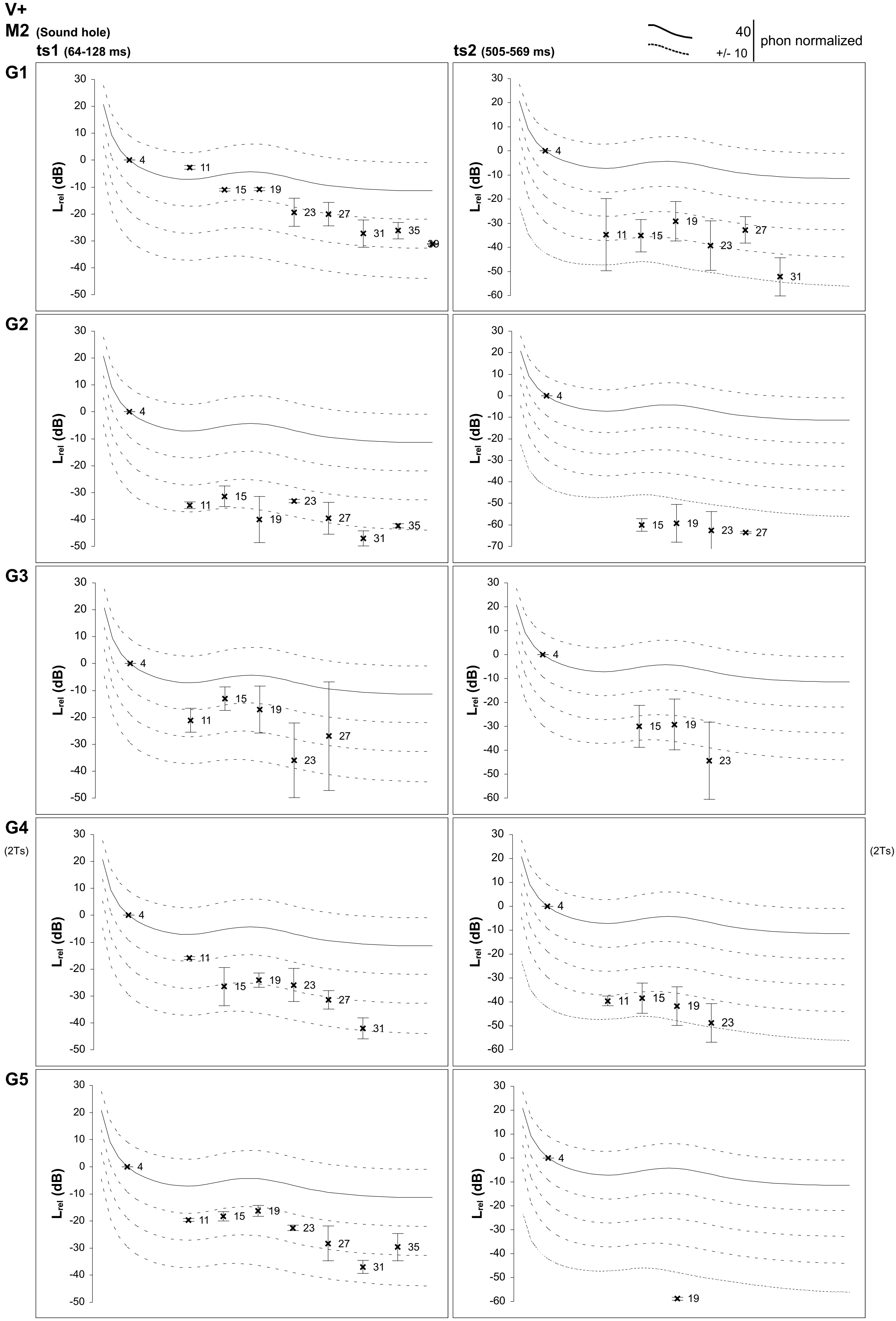
ts1 (64-128 ms) **ts2** (505-569 ms)

40 | phon normalized
+/- 10

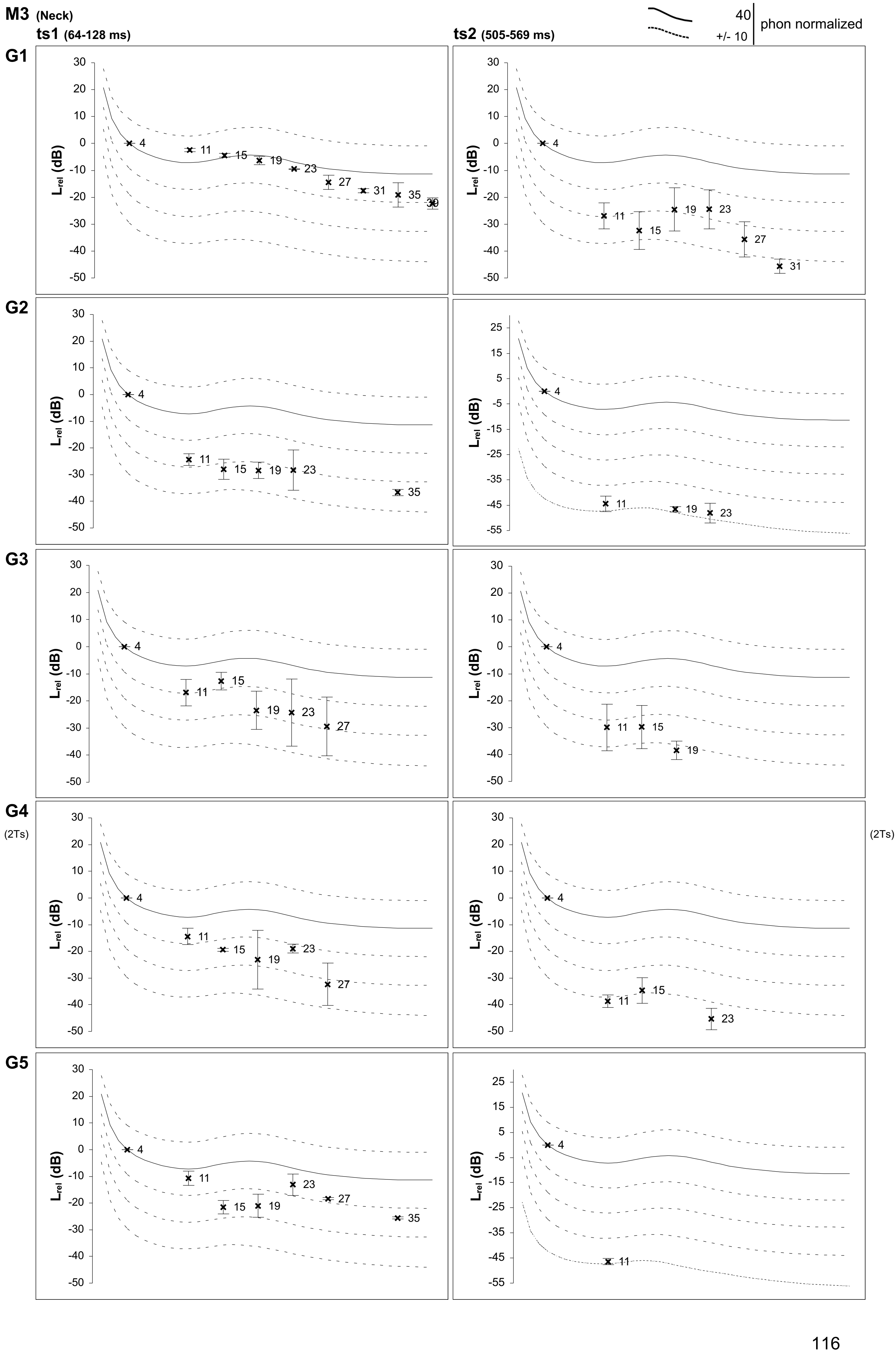
G1
G2
G3
G4 (2Ts)
G5



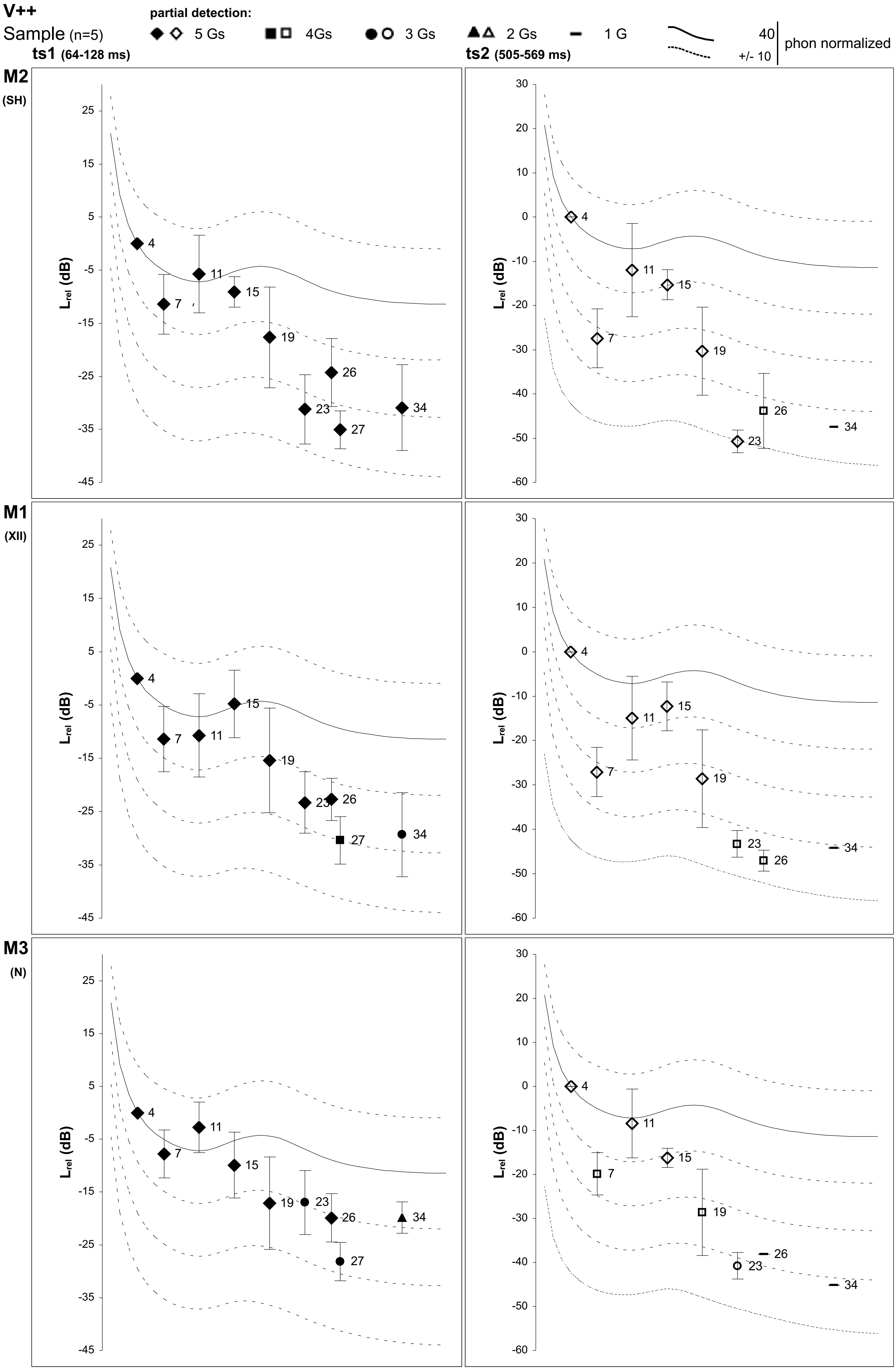
(2Ts)


V+
M2 (Sound hole)
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
(2Ts)
G5
L_rel (dB)

V+
M3 (Neck)



40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
G1
G2
G3
G4
(2Ts)
G5
L_{rel} (dB)

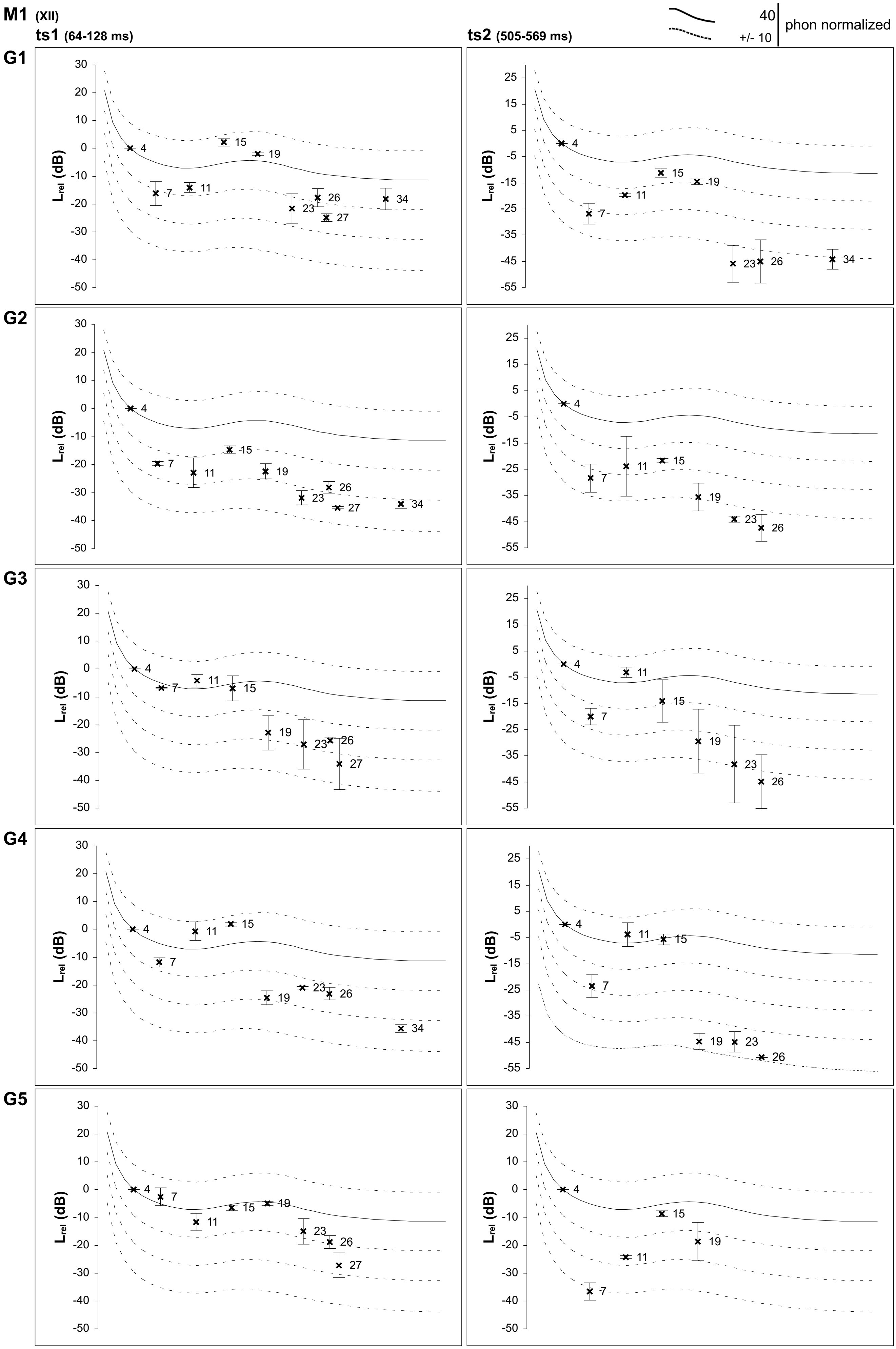


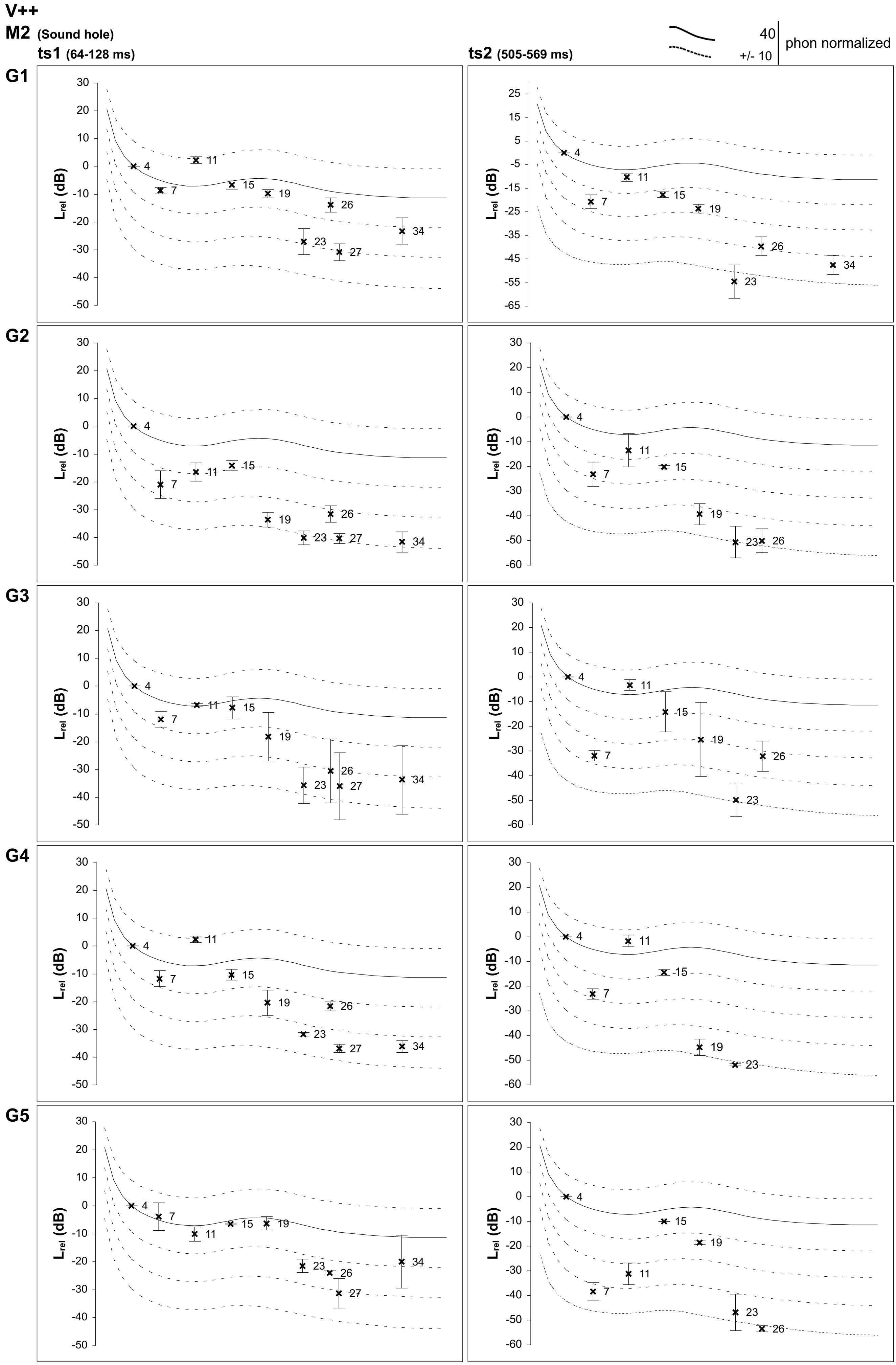
V++
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L rel (dB)

V++

M1 (XII)

ts1 (64-128 ms) **ts2** (505-569 ms)

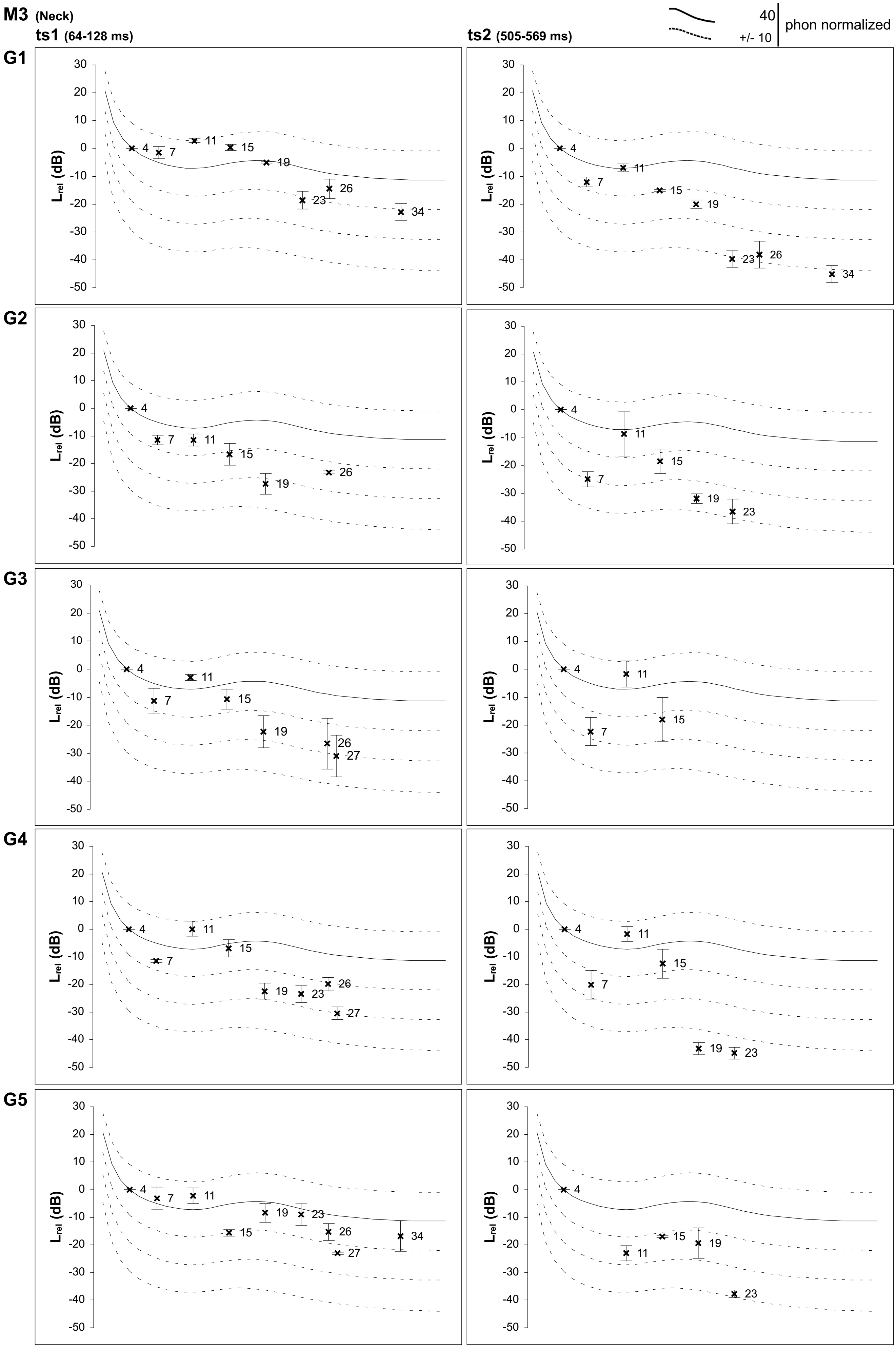


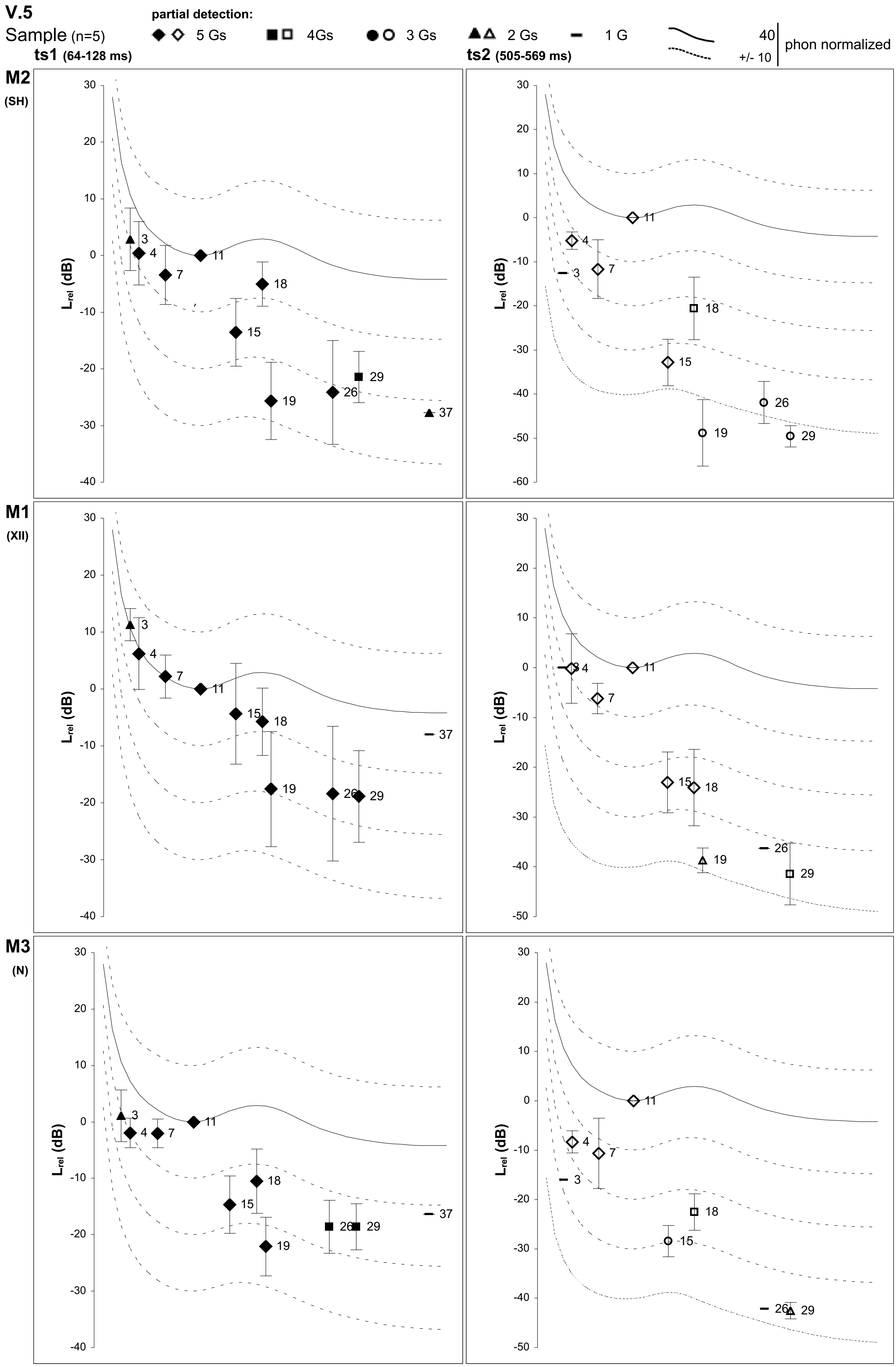

V++
M2 (Sound hole)
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
Lrel (dB)

V++

M3 **(Neck)**

ts1 **(64-128 ms)** **ts2** **(505-569 ms)**




V.5
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
Lrel (dB)

V.5

M1 (XII)

40 — phon normalized
+/- 10 — phon normalized

ts1 (64-128 ms) | **ts2** (505-569 ms)

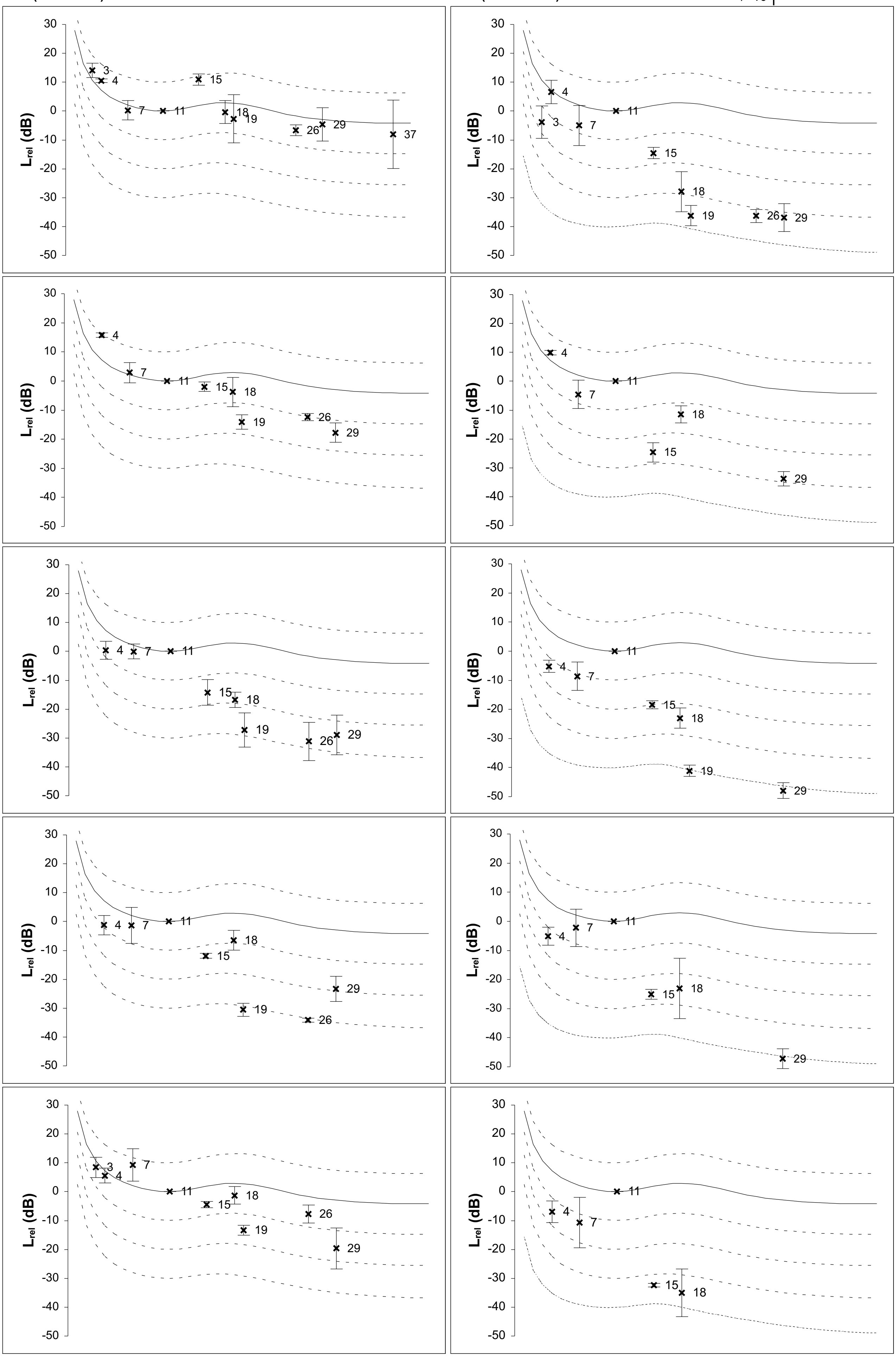
G1

G2
(2Ts)

G3

G4

G5



V.5

M2 (Sound hole)

40 | +/- 10 | phon normalized

ts1 (64-128 ms) **ts2** (505-569 ms)

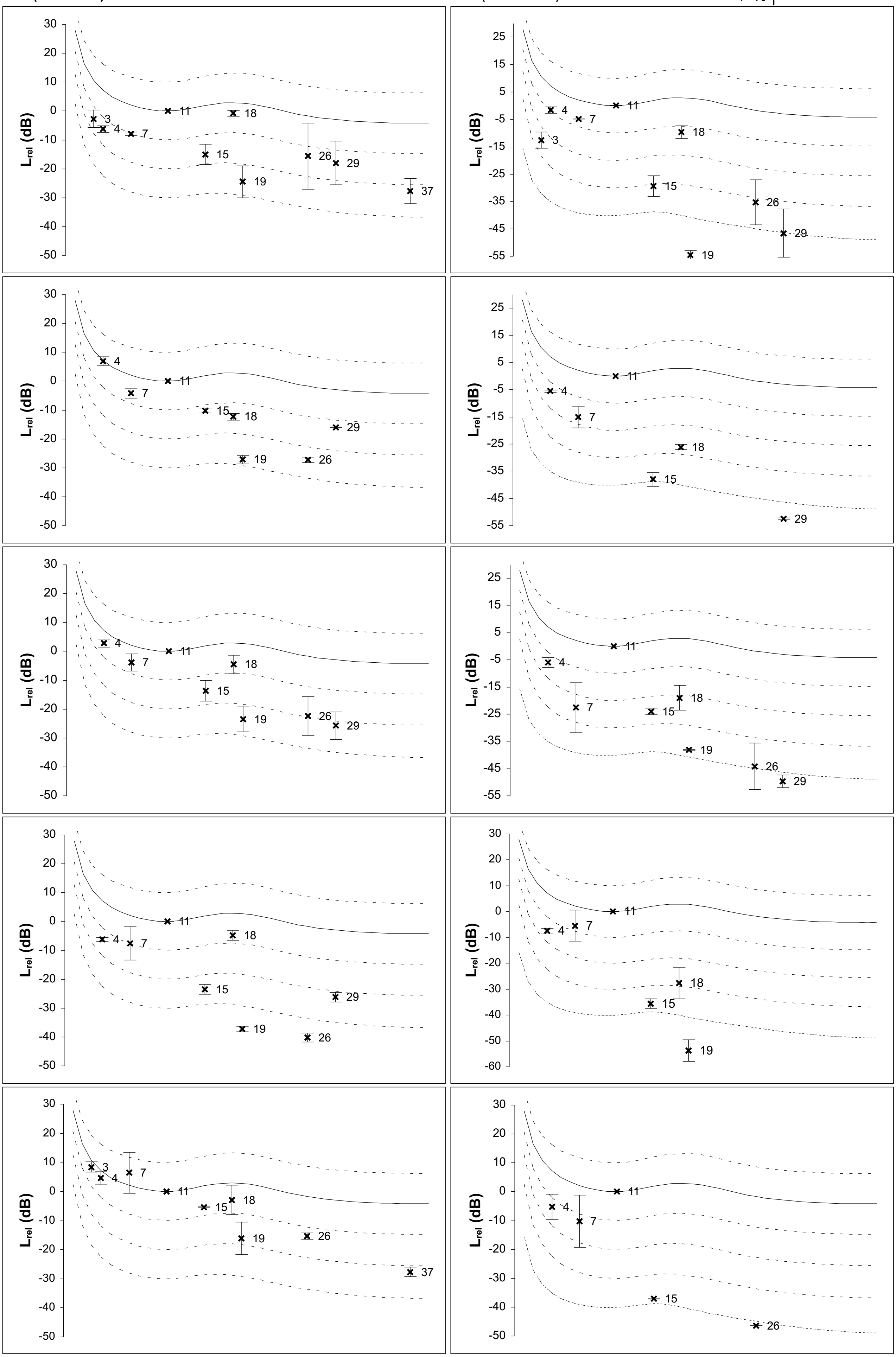
G1

G2 (2Ts)

G3

G4

G5



V.5

M3 (Neck)

40 phon normalized
+/- 10

ts1 (64-128 ms) **ts2** (505-569 ms)

G1

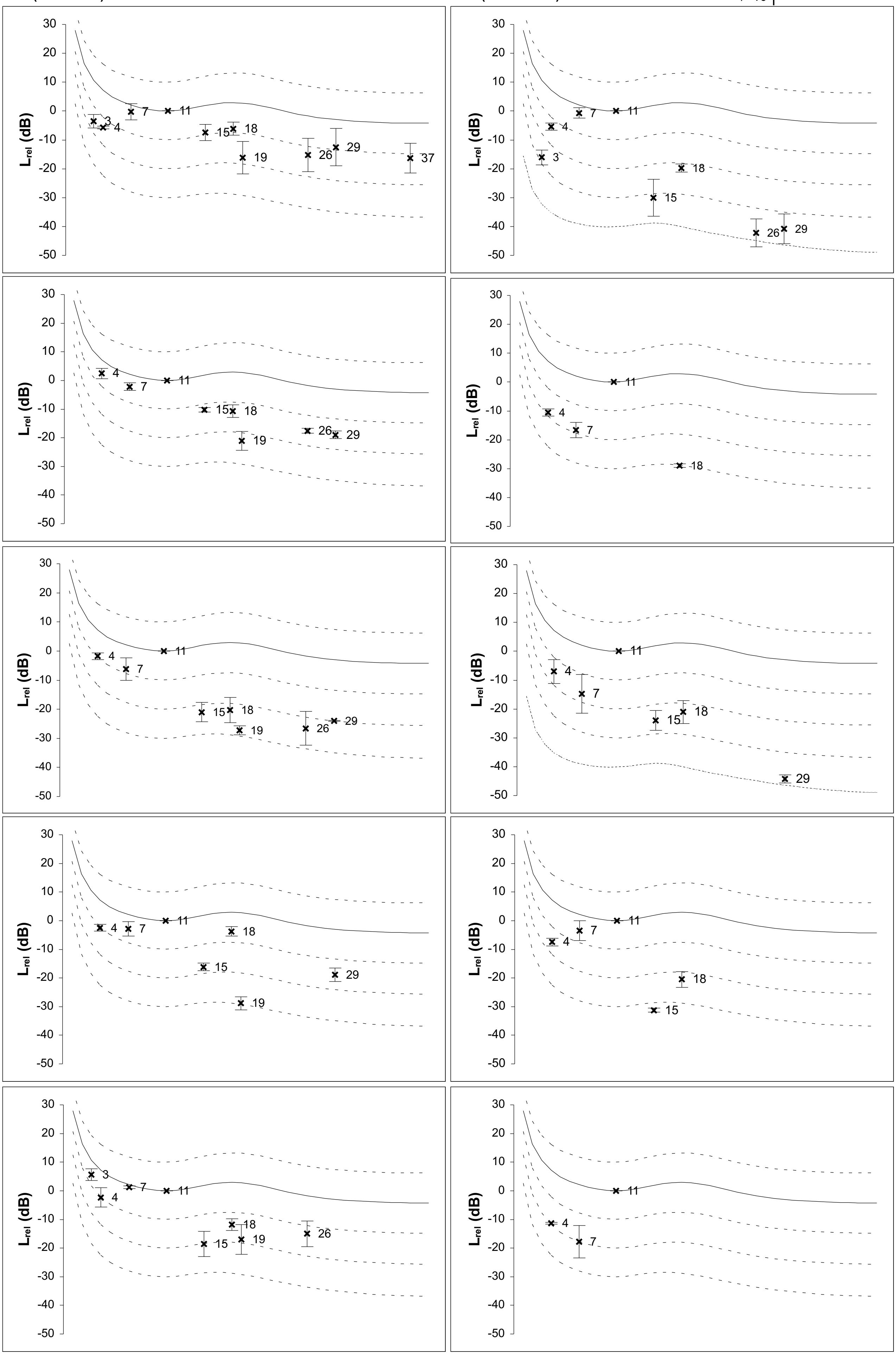
G2
(2Ts)

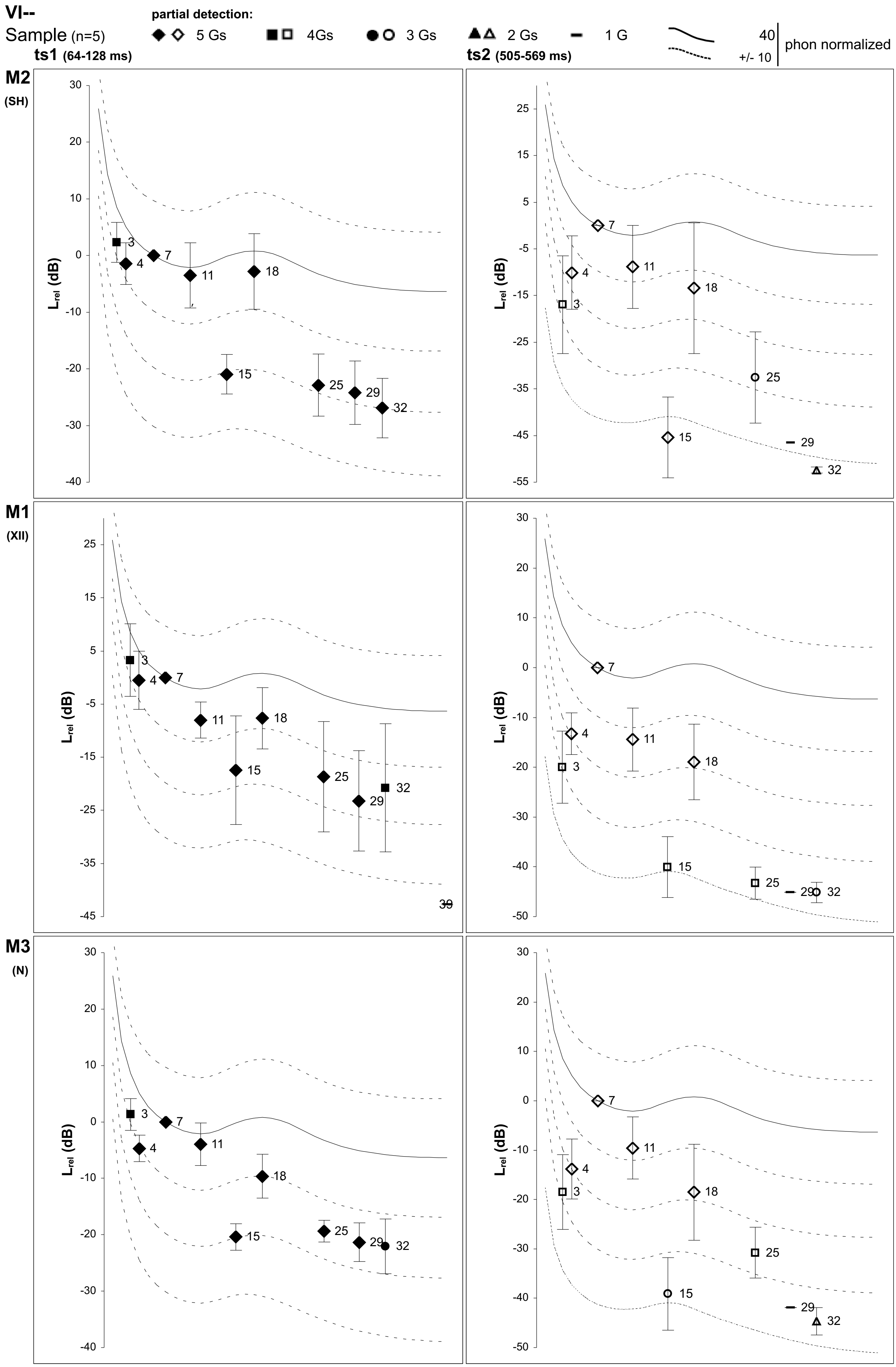
(2Ts)

G3

G4

G5





VI--
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
Lrel (dB)

VI--

M1 (XII)

ts1 (64-128 ms) **ts2** (505-569 ms)

40 / +/- 10 phon normalized

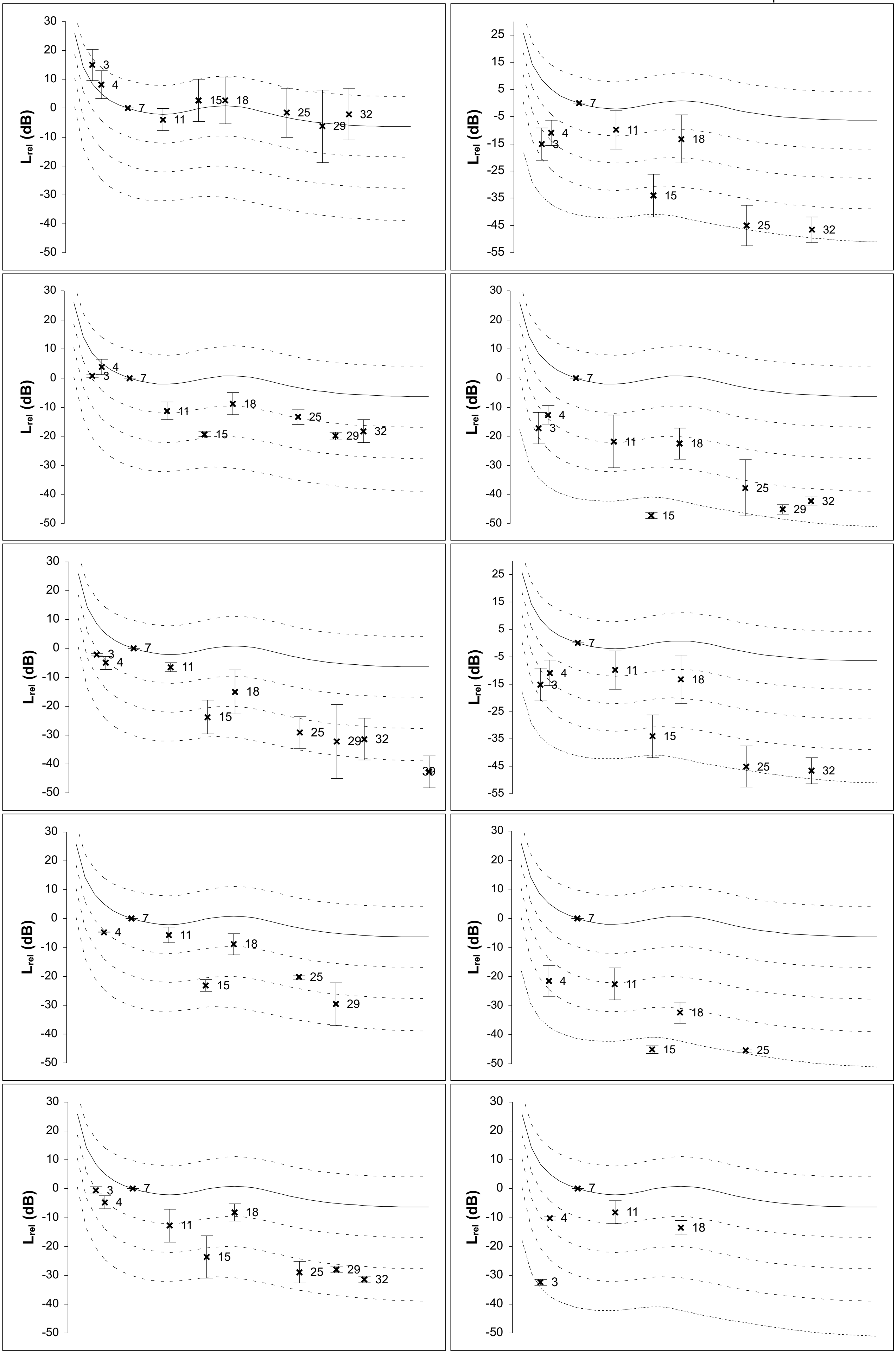
G1

G2

G3

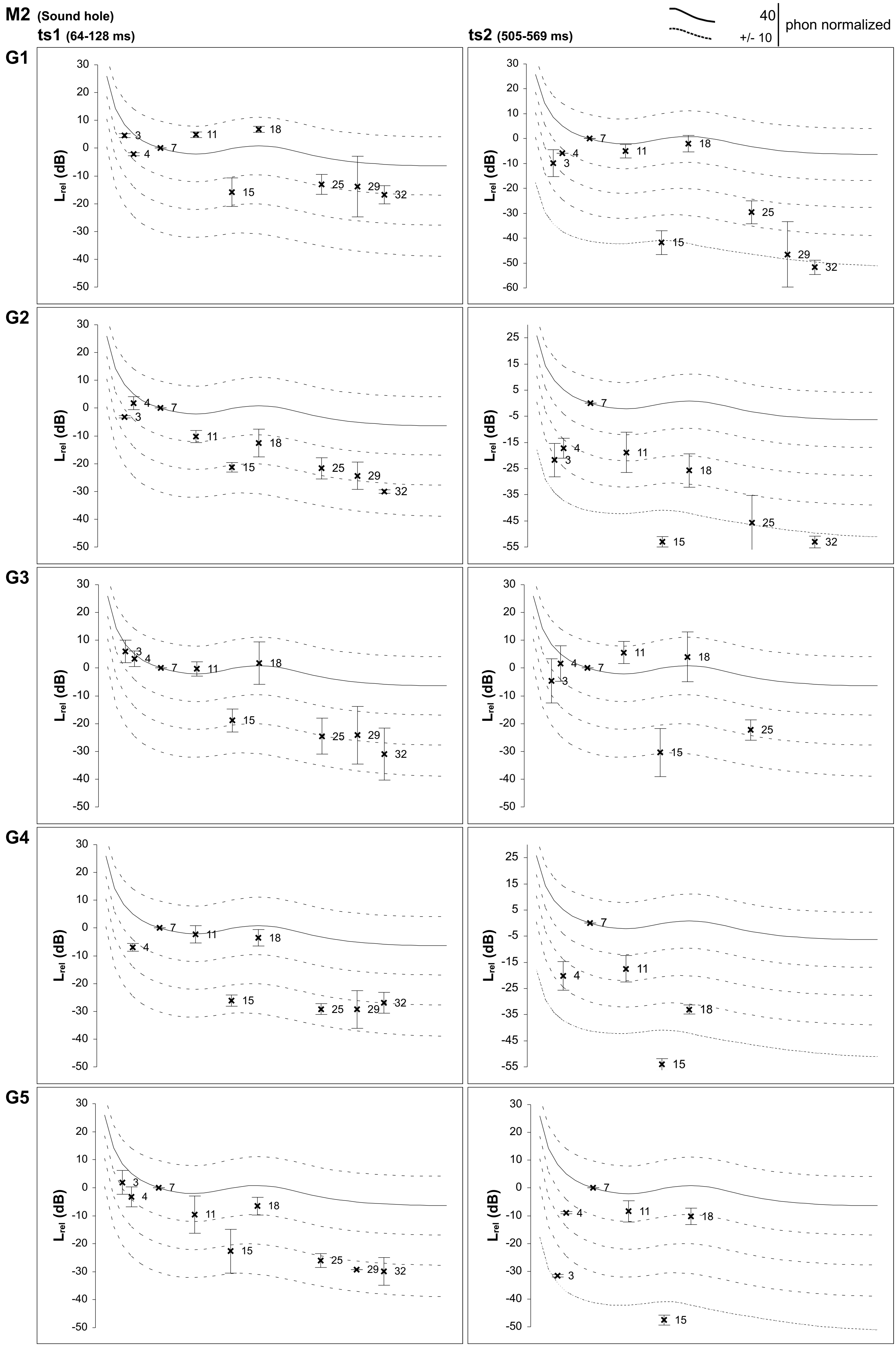
G4

G5



VI--

M2 (Sound hole)

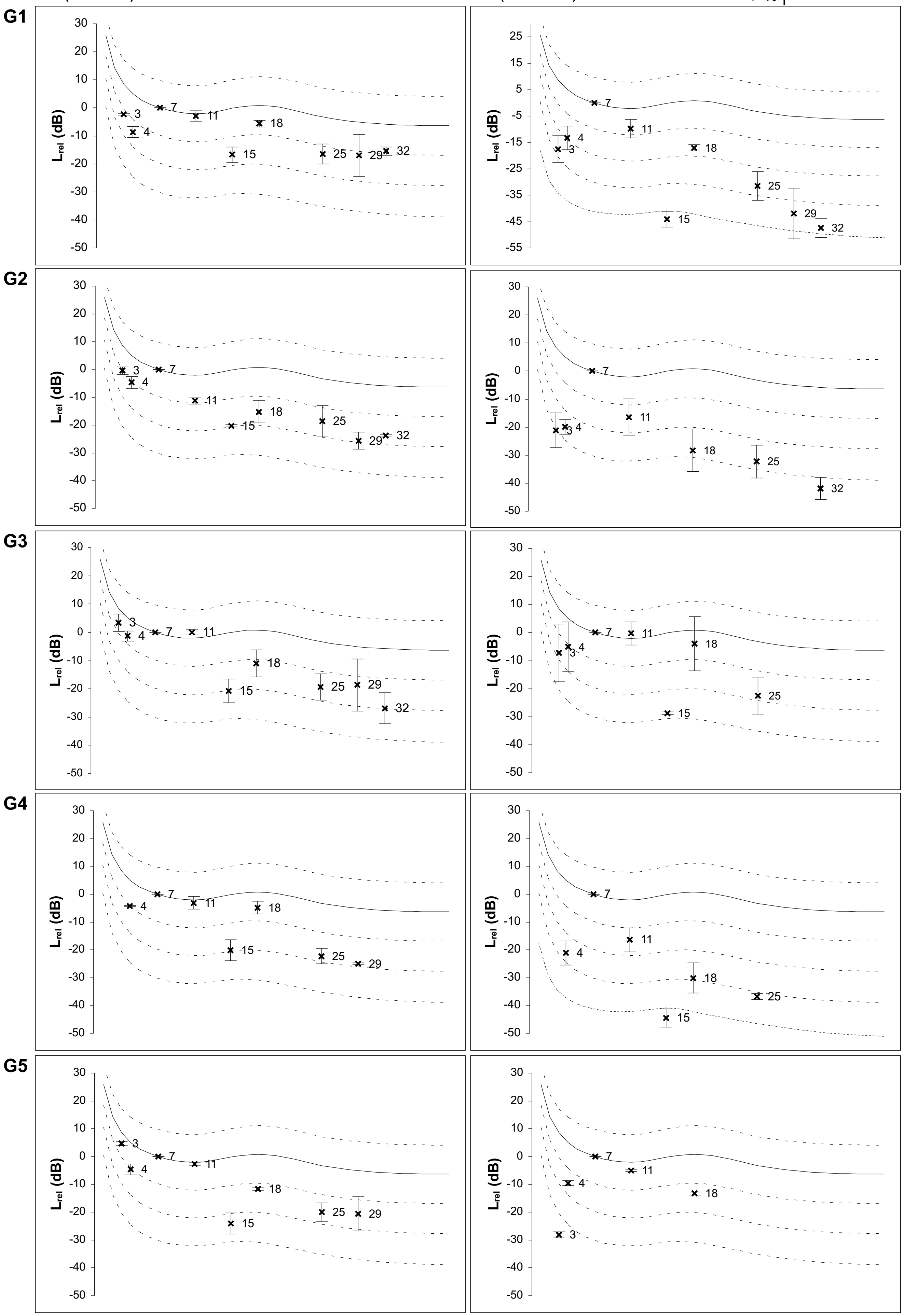


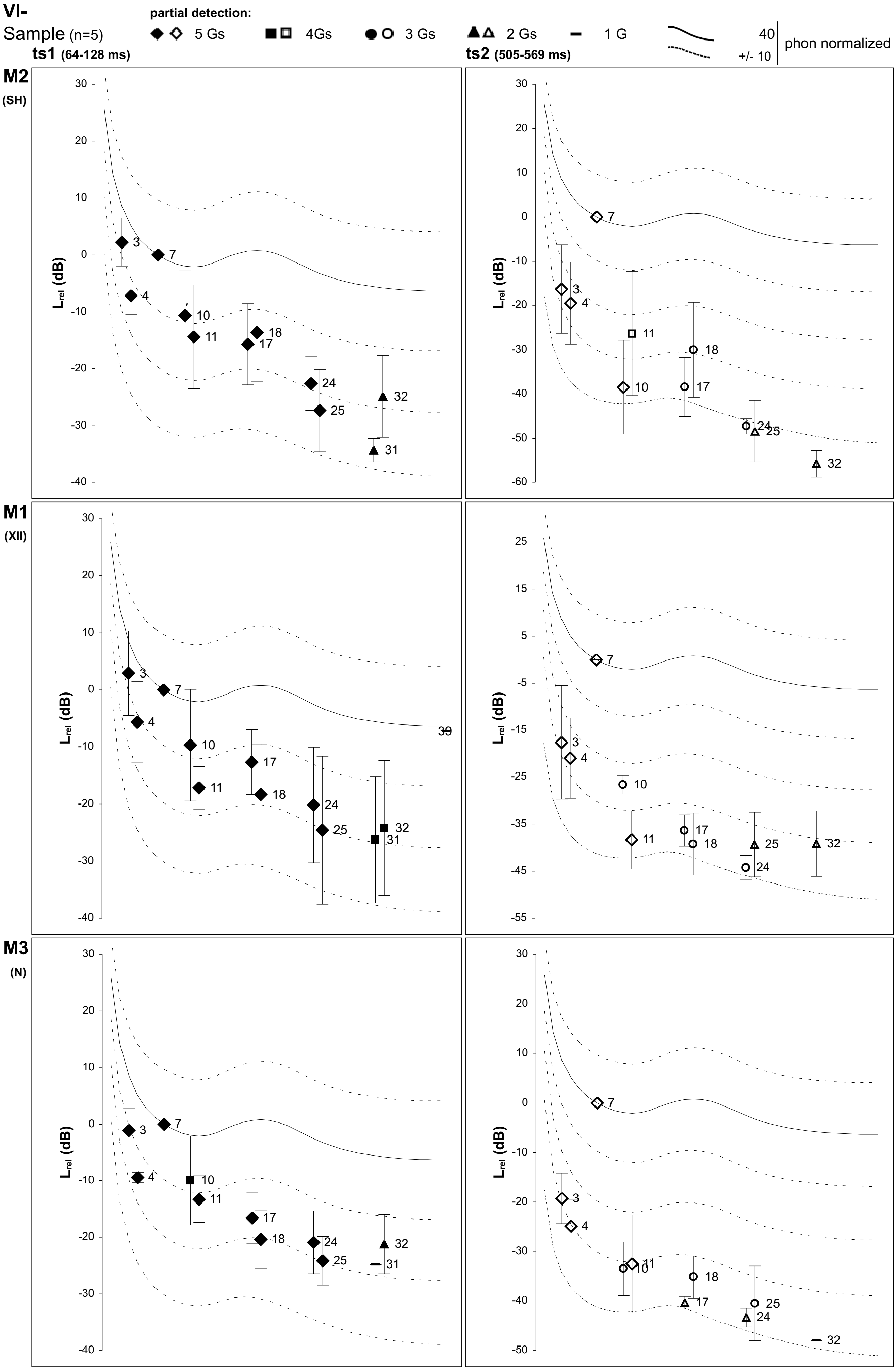
VI--

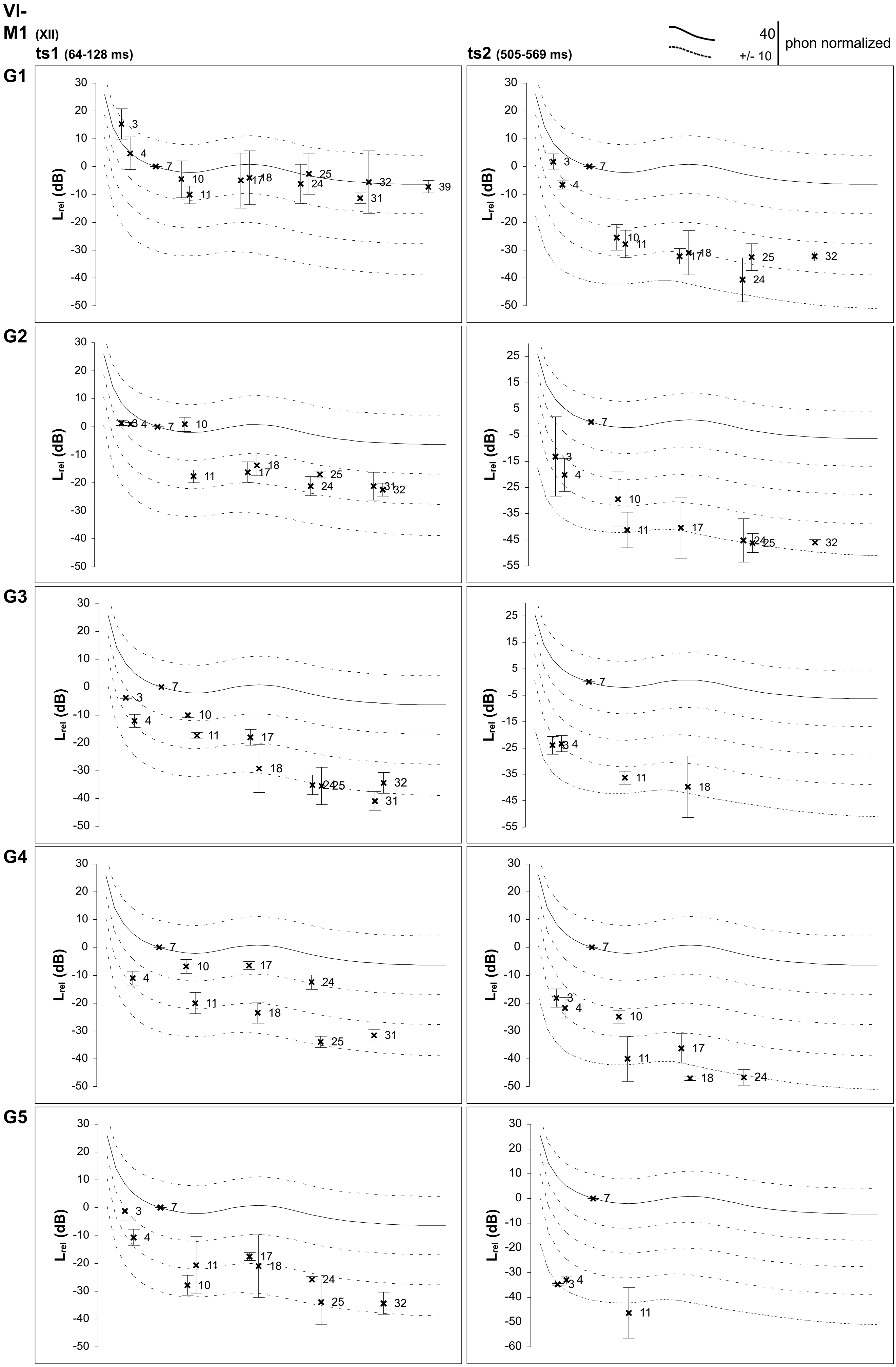
M3 (Neck)

ts1 (64-128 ms) **ts2** (505-569 ms)

40 / +/- 10 phon normalized




VI-
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
Lrel (dB)


VI-
M1 (XII)
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
Lrel (dB)

VI-
M2 **(Sound hole)**

ts1 **(64-128 ms)** **ts2** **(505-569 ms)**

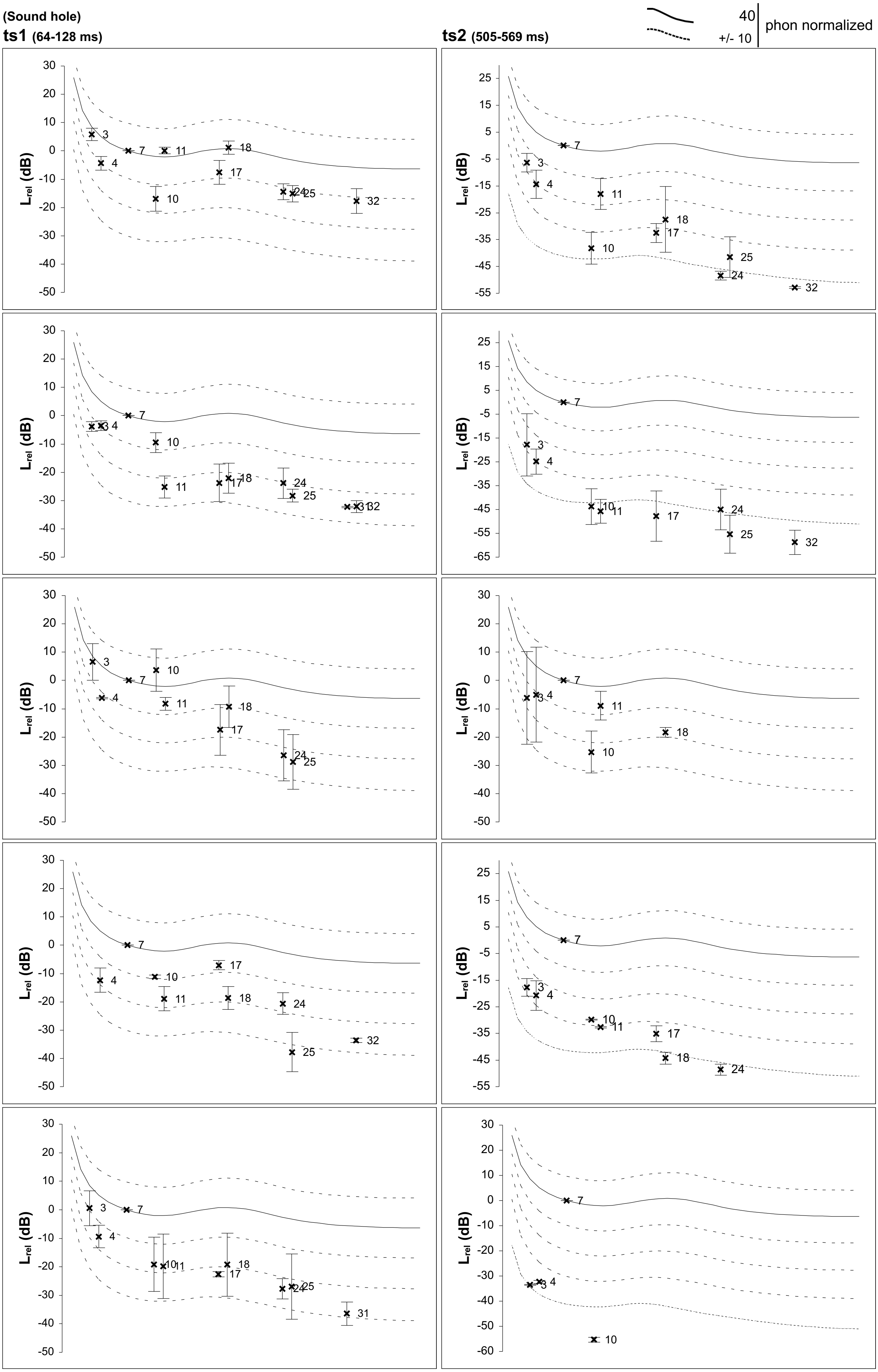
G1

G2

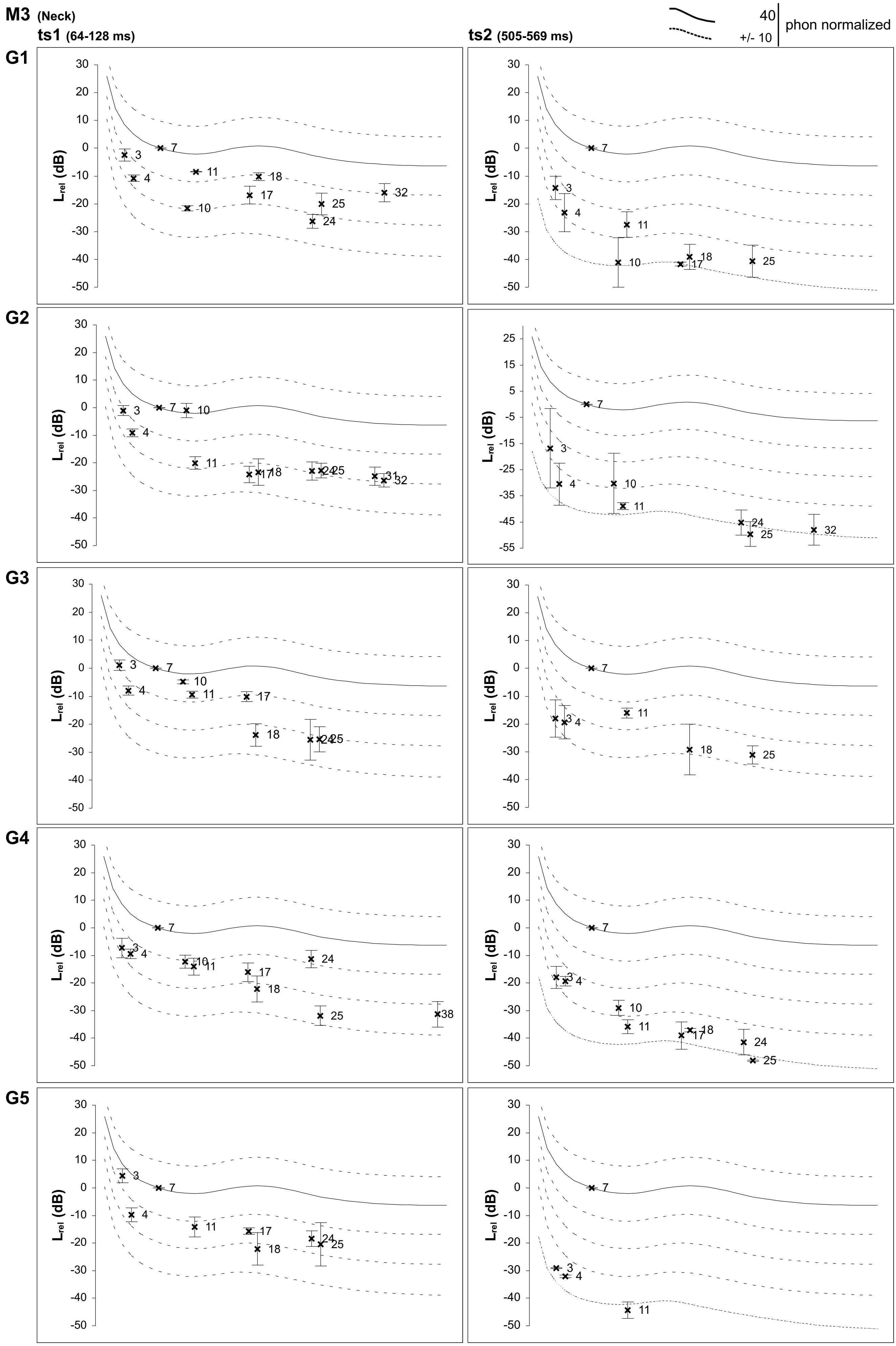
G3

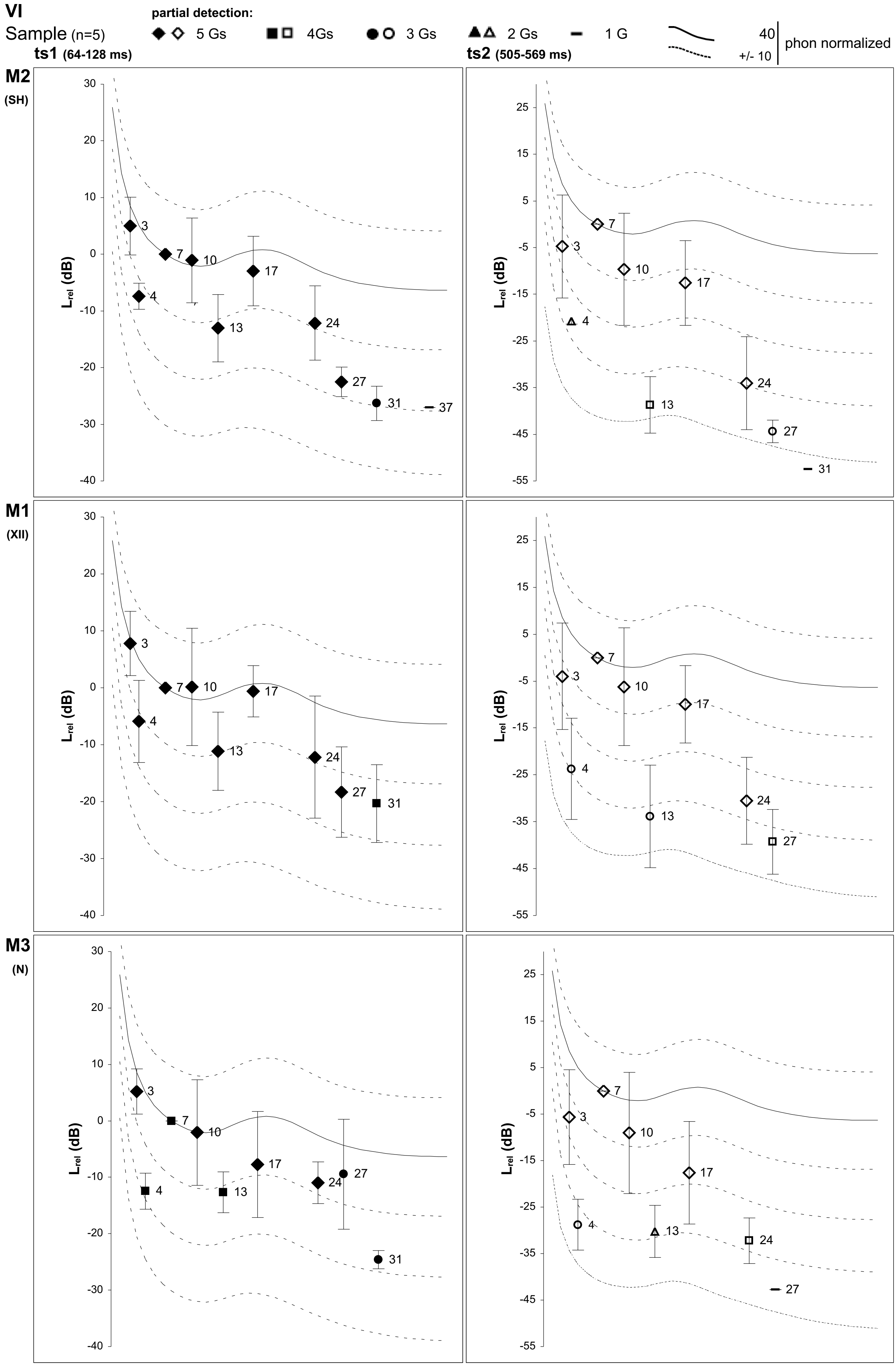
G4

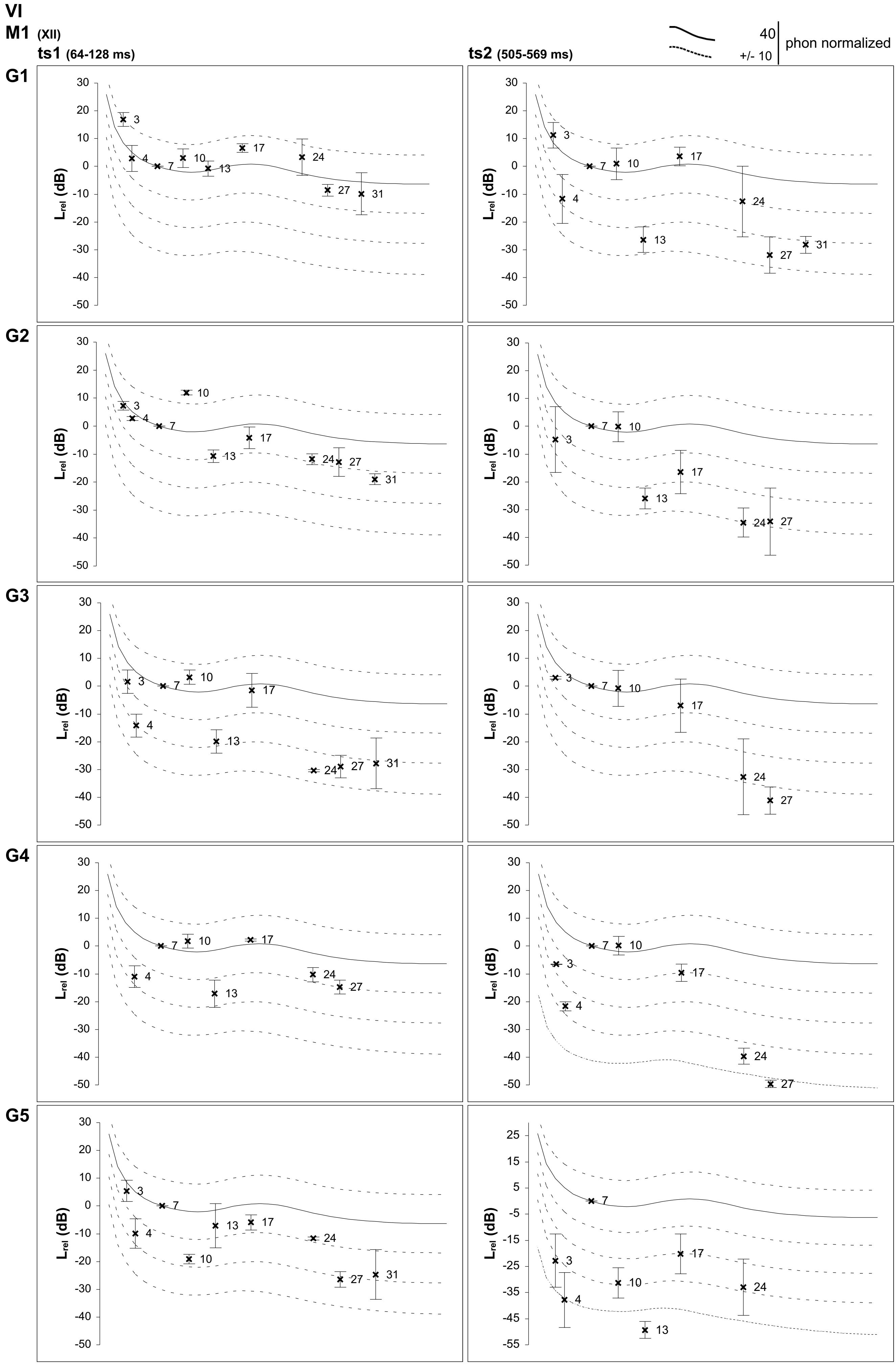
G5



VI-
M3 (Neck)

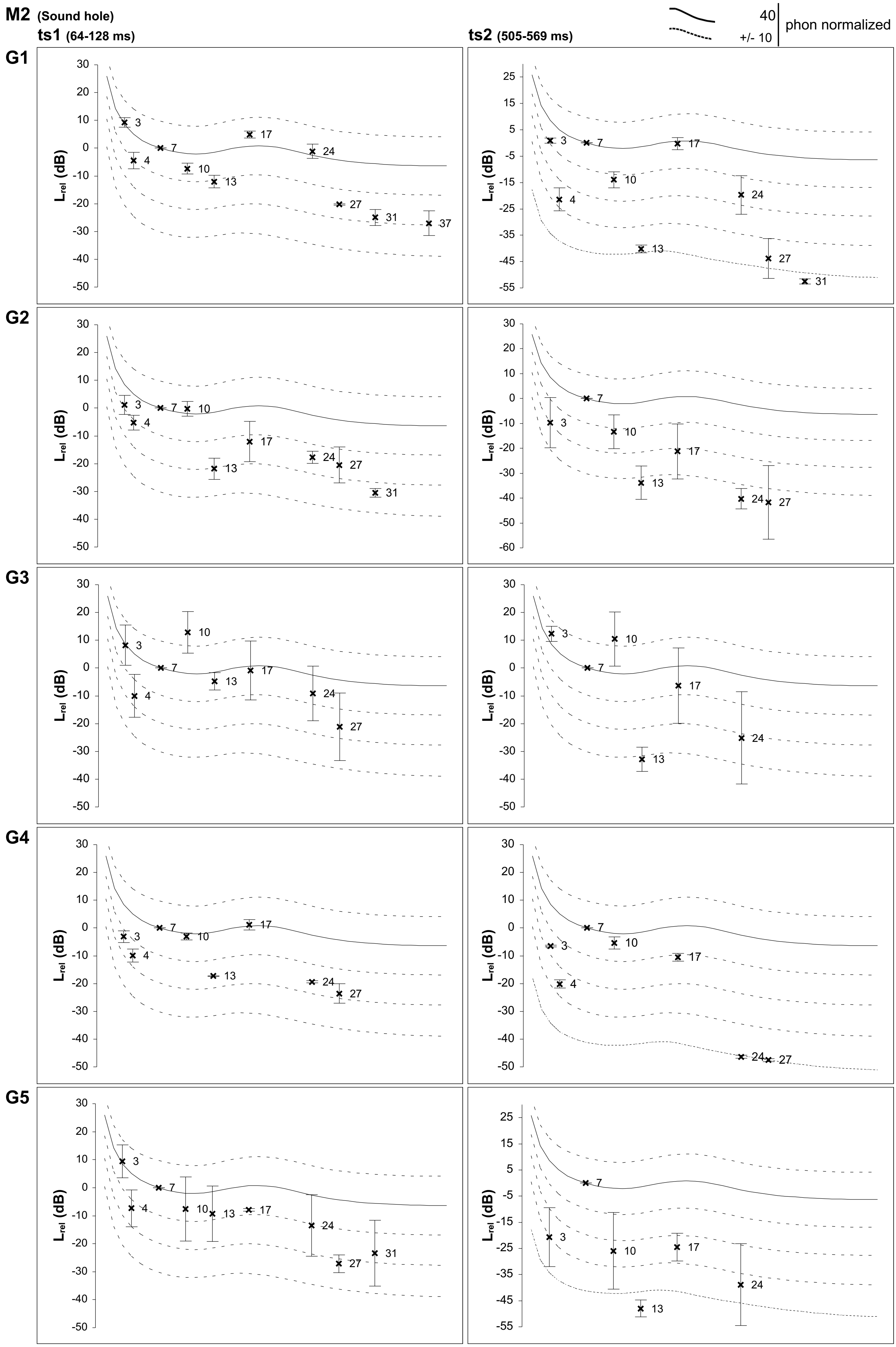

ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
L_{rel} (dB)


VI
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_rel (dB)


VI
M1 (XII)
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
Lrel (dB)

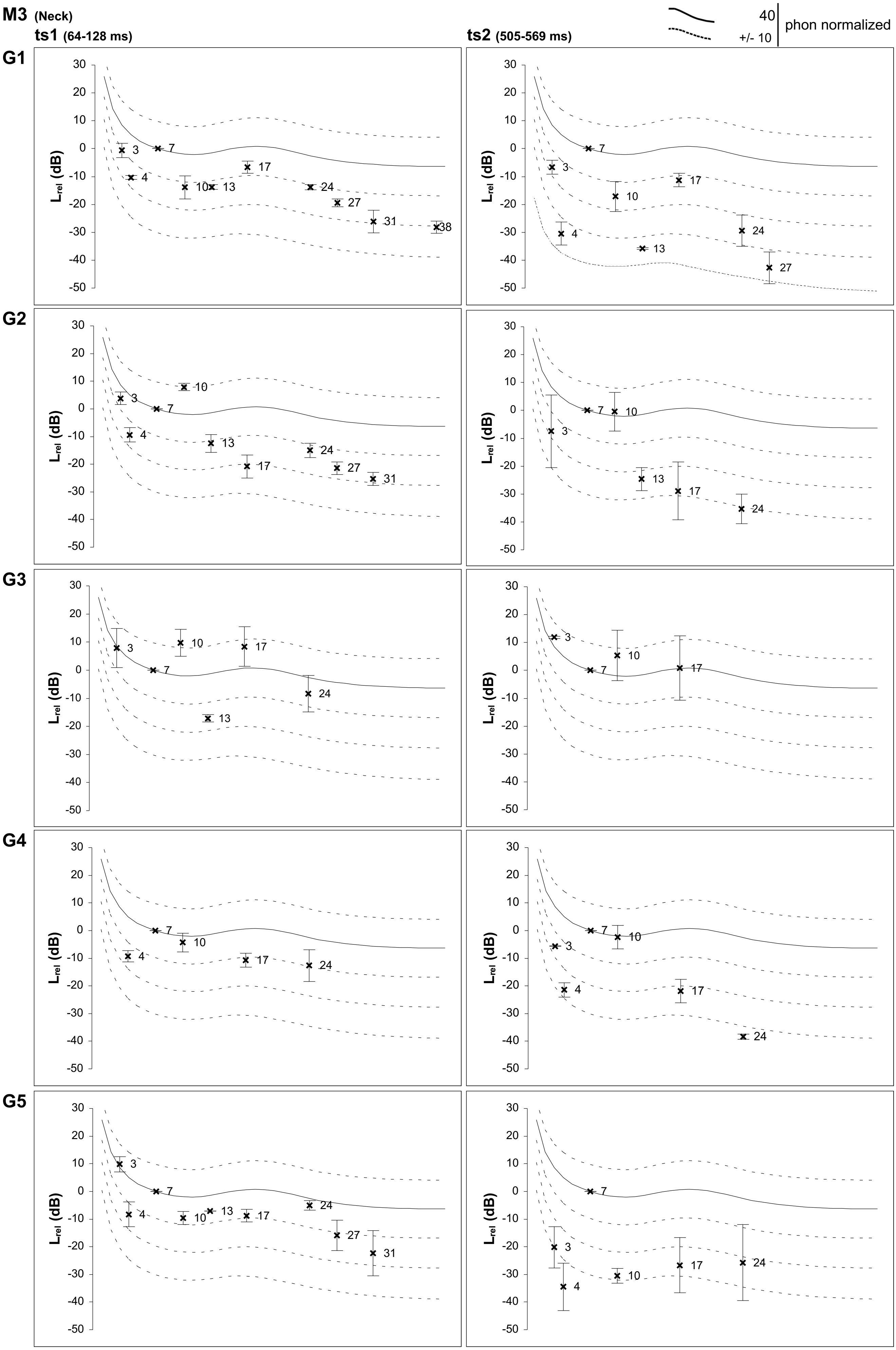
VI

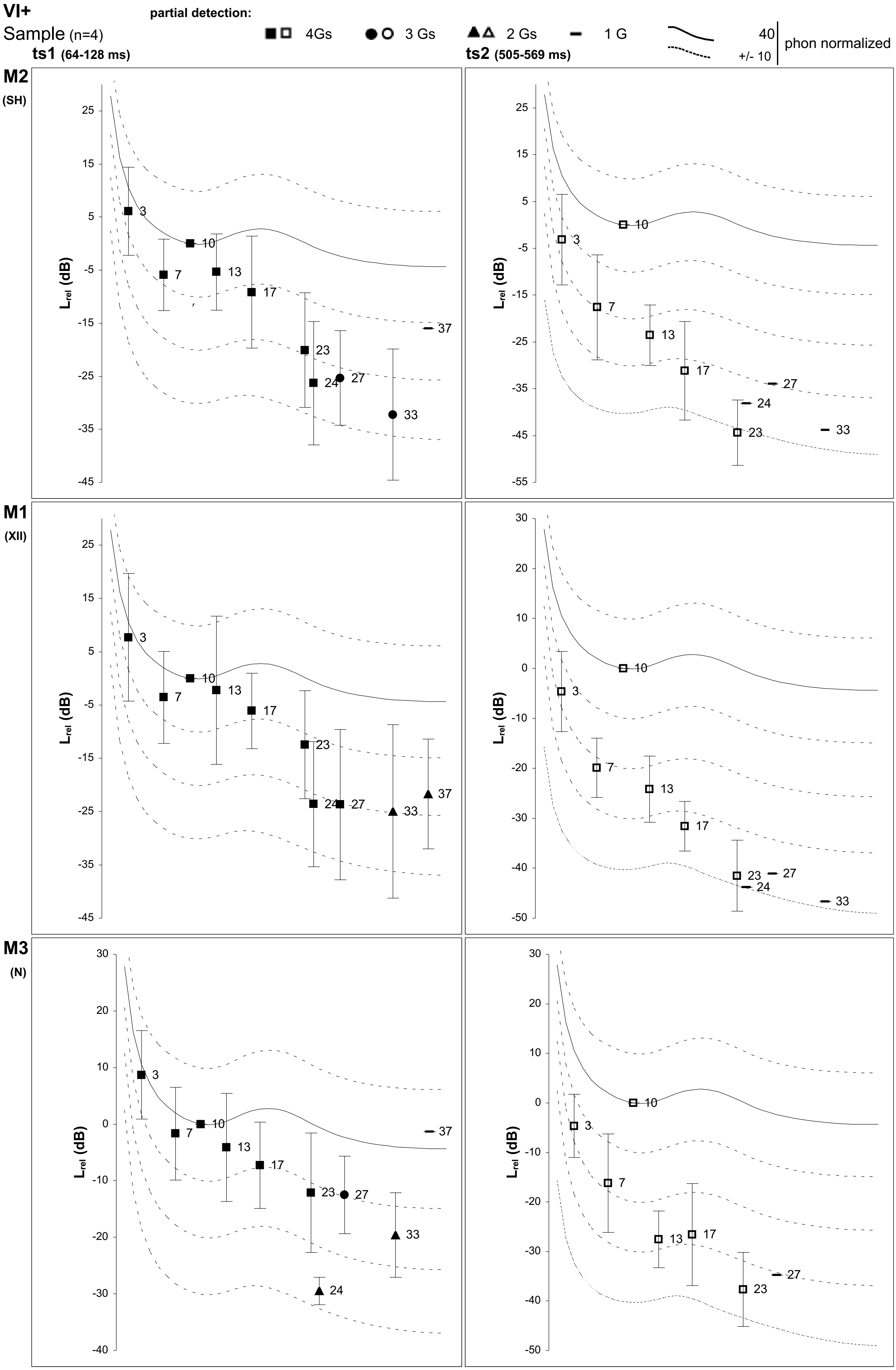
M2 (Sound hole)

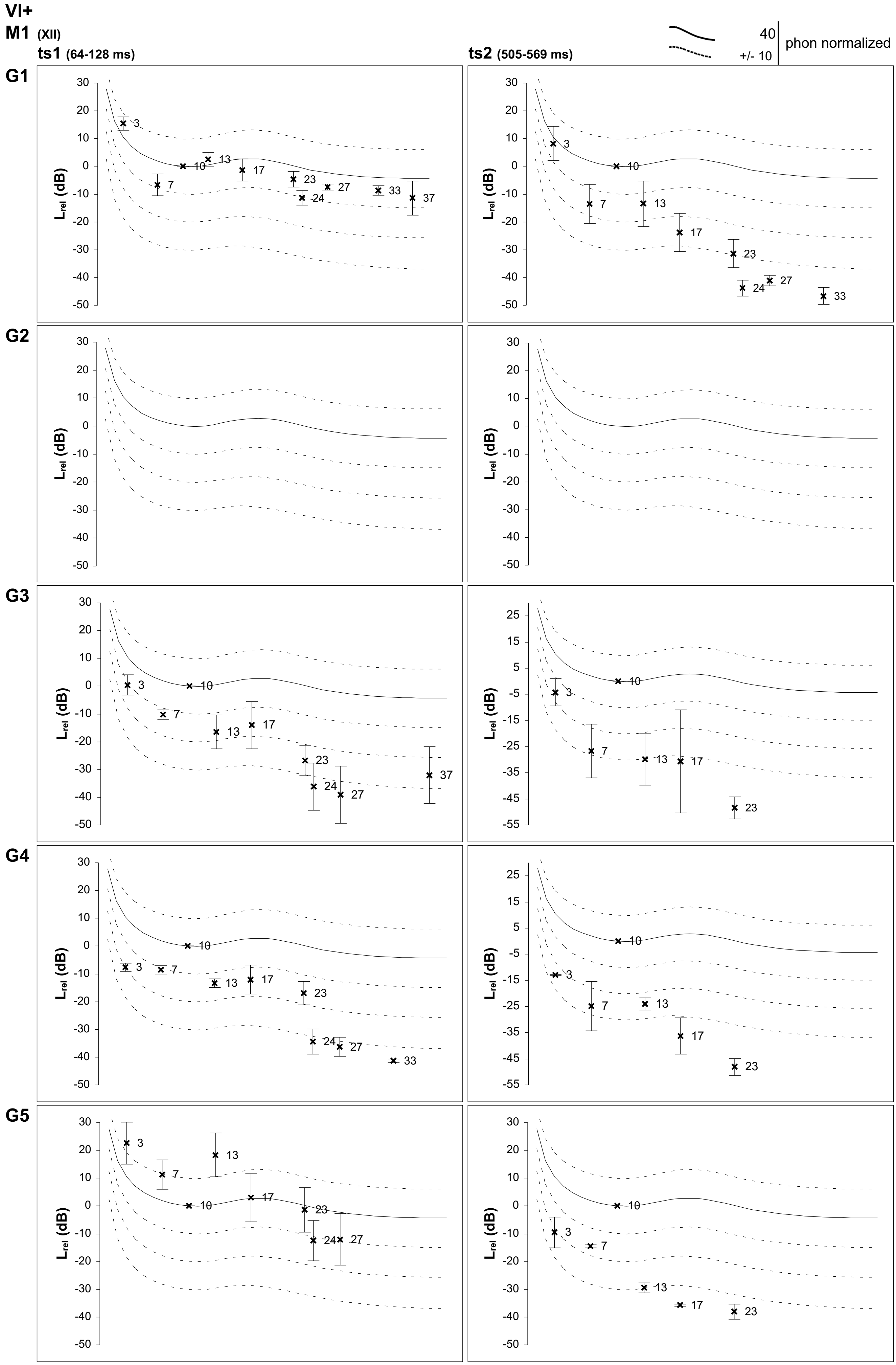


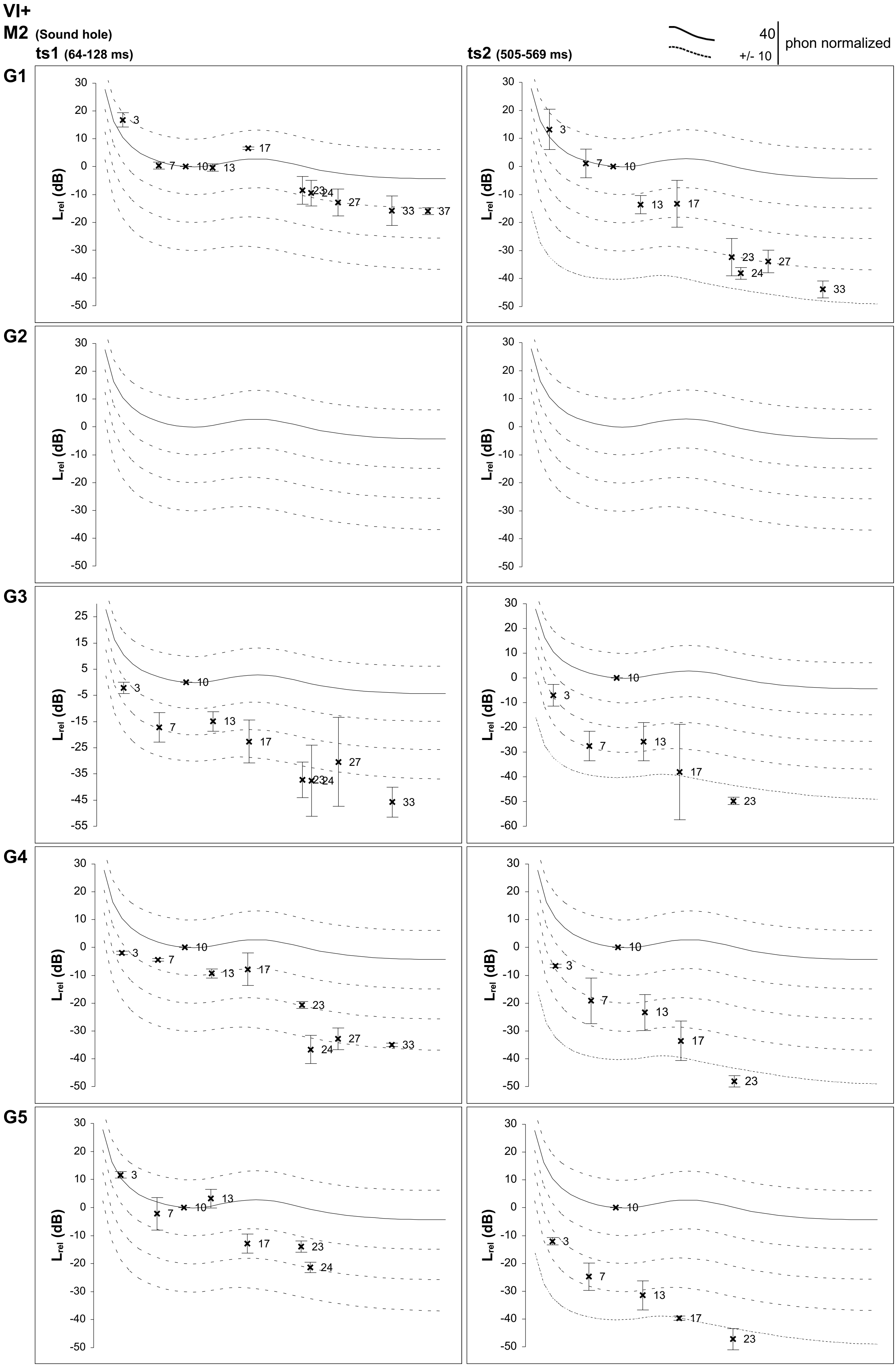
VI

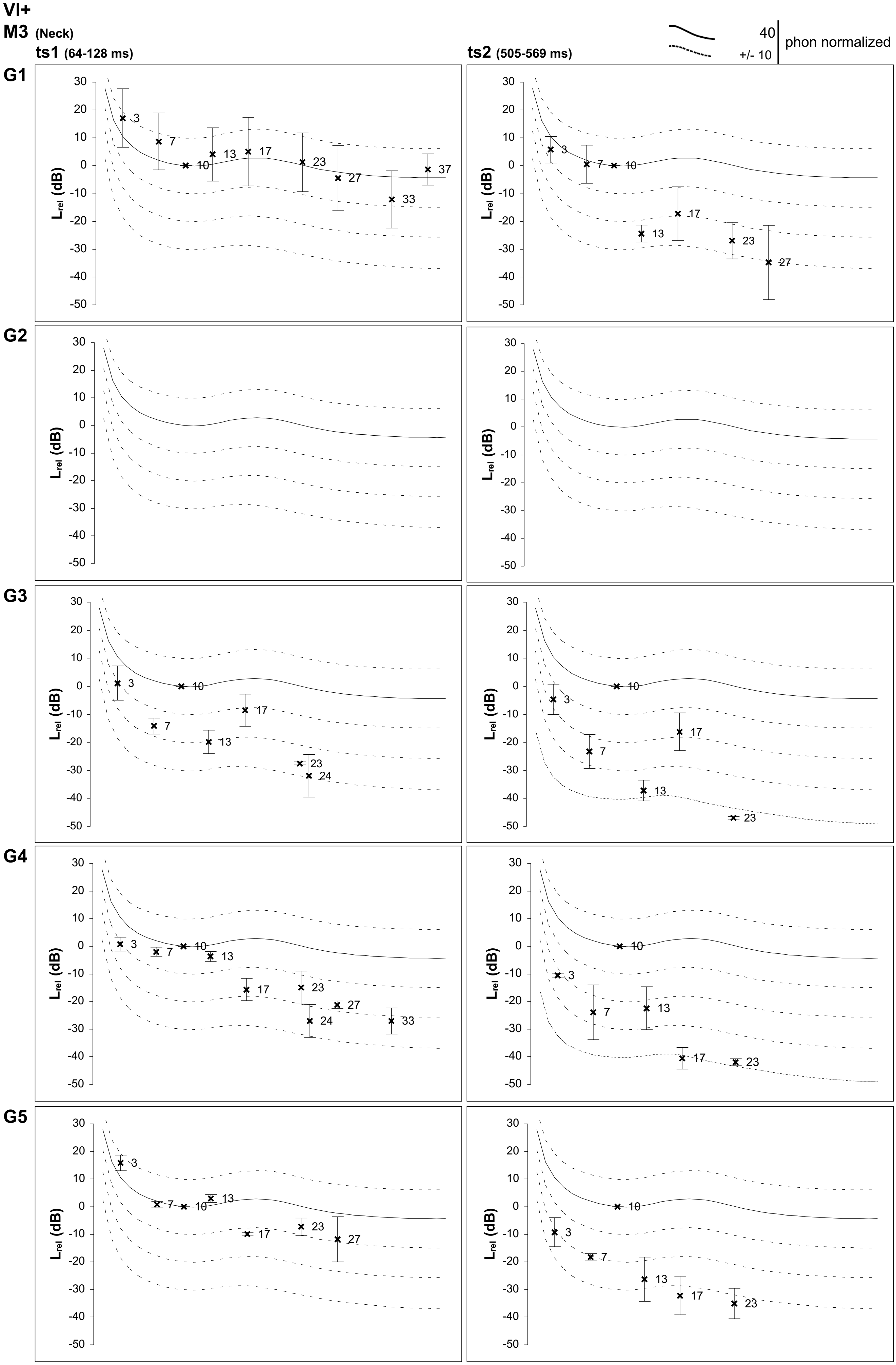
M3 (Neck)

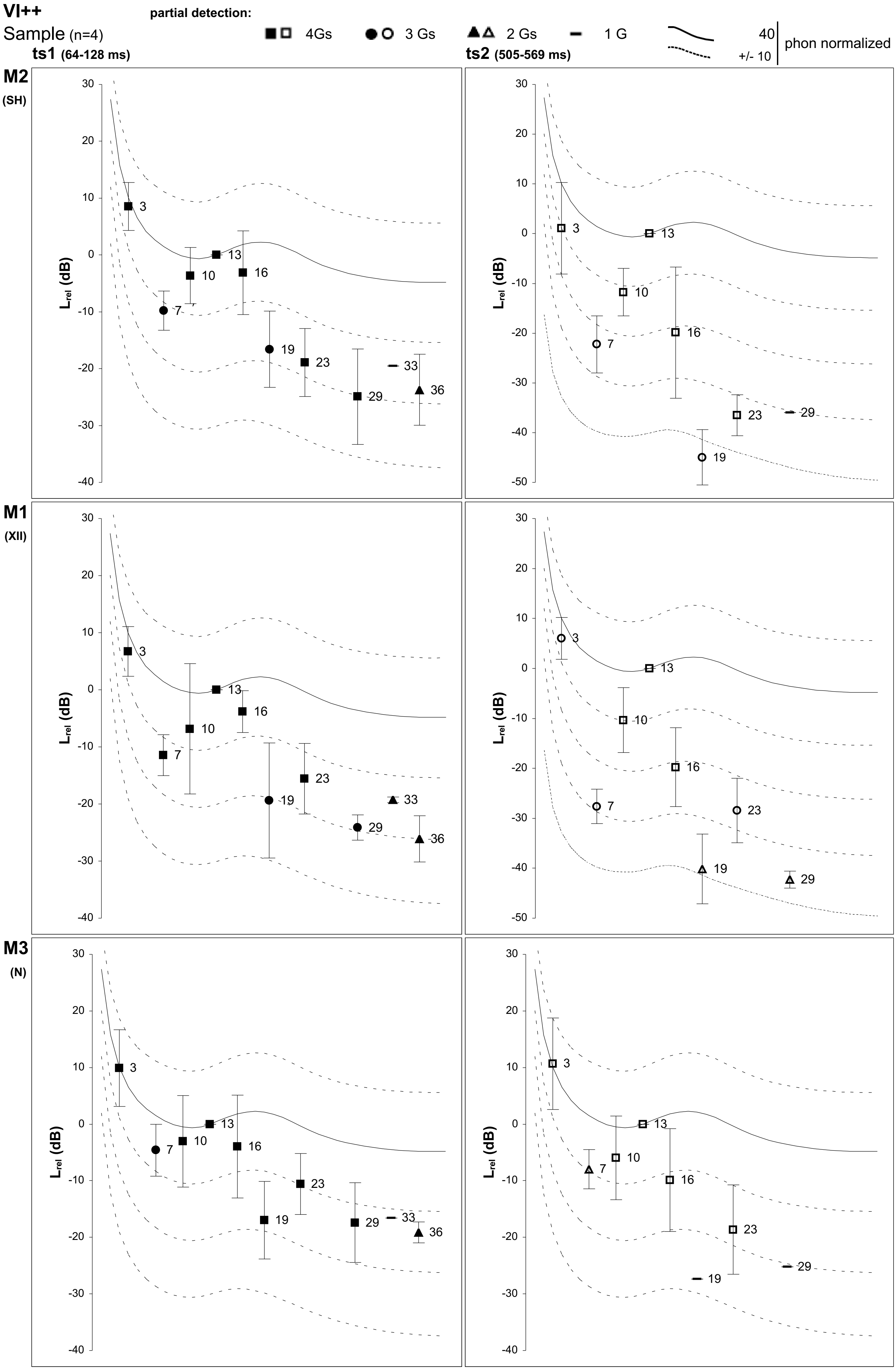

ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
L_{rel} (dB)
30
20
10
0
-10
-20
-30
-40
-50

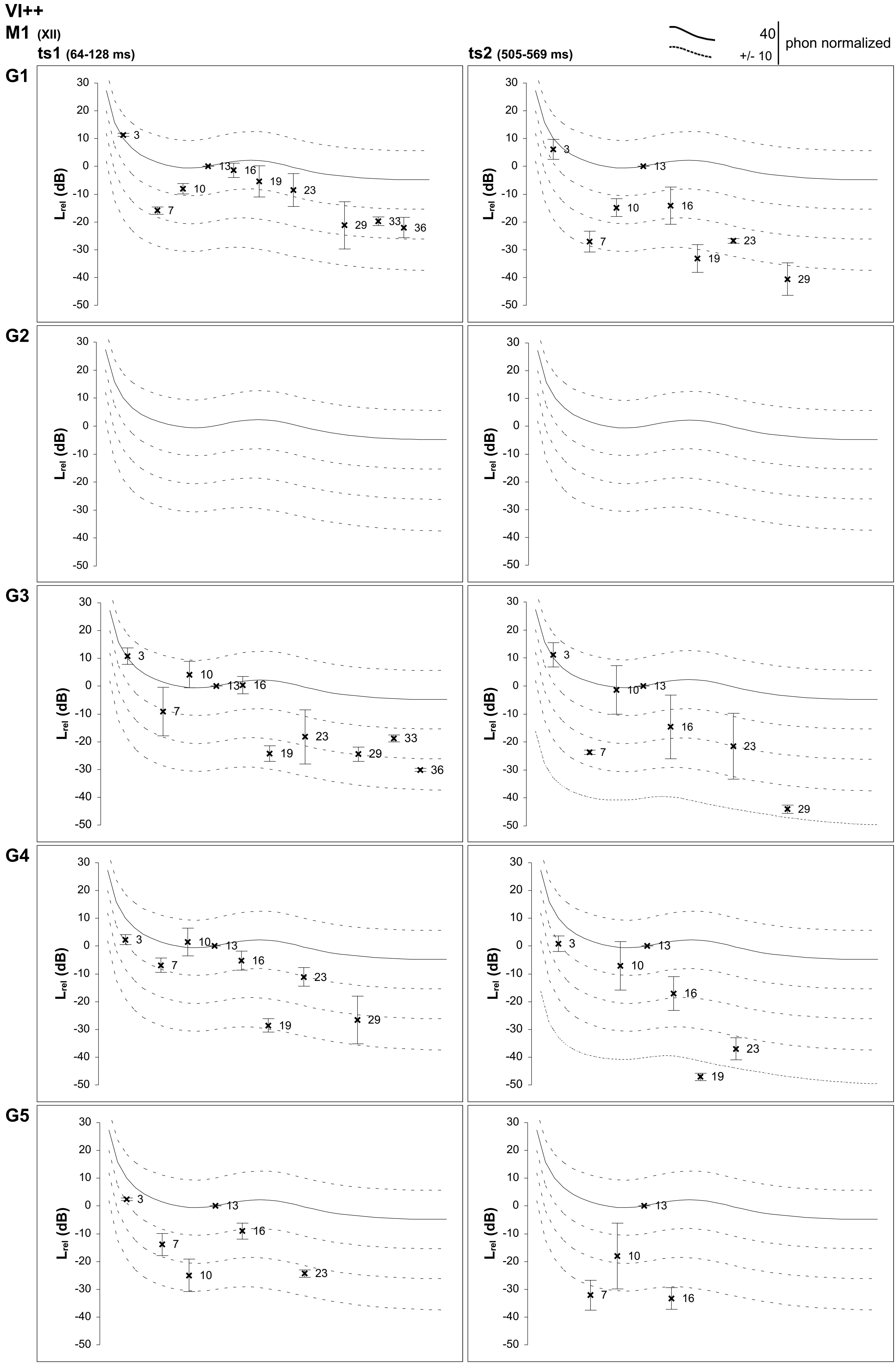

VI+
Sample (n=4)
partial detection:
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_rel (dB)
3
7
10
13
17
23
24
27
33
37


VI+
M1 (XII)
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
Lrel (dB)


VI+
M2 (Sound hole)
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
L_rel (dB)

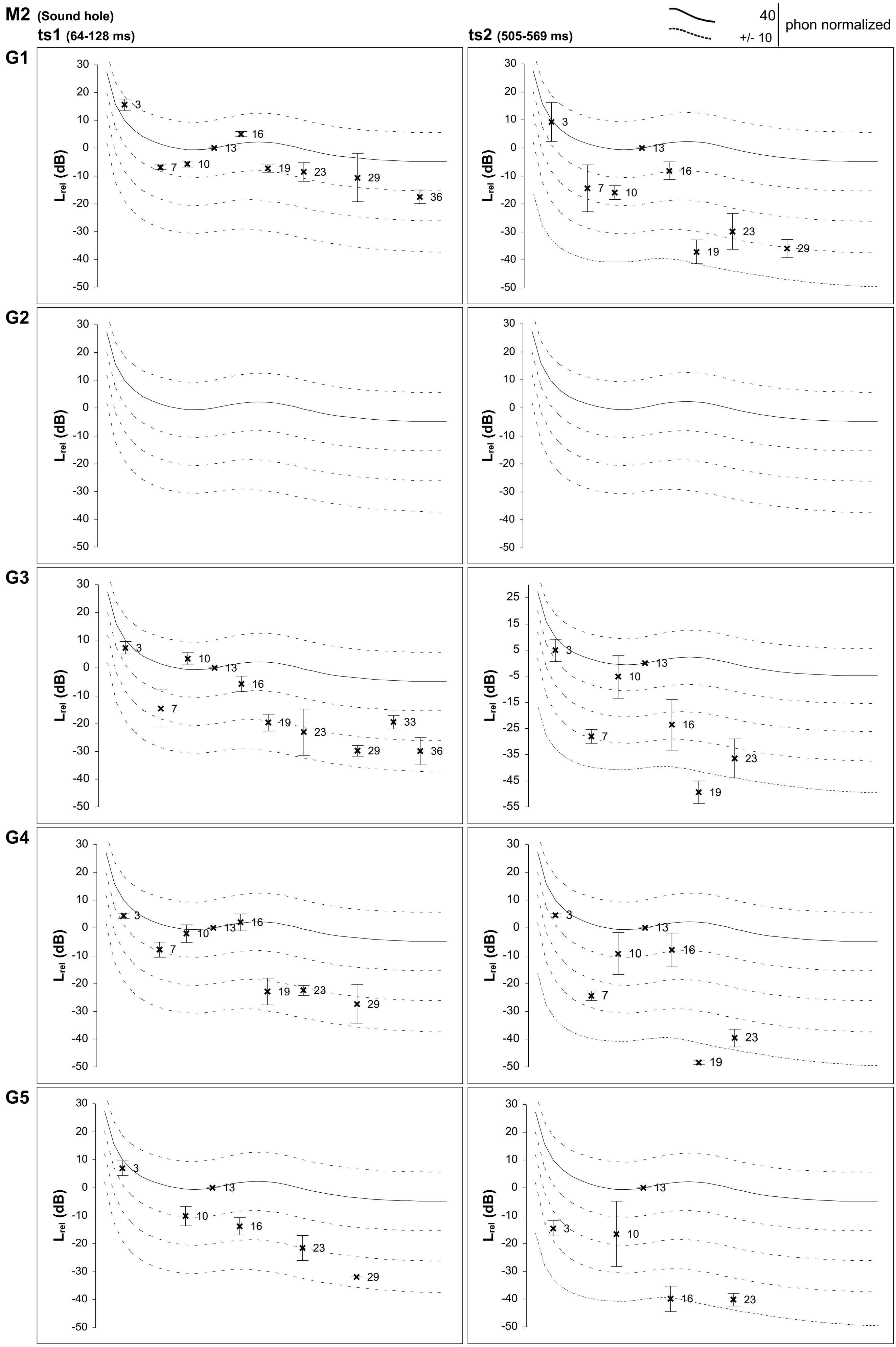

VI+
M3 (Neck)
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
L_rel (dB)
30
20
10
0
-10
-20
-30
-40
-50
3
7
10
13
17
23
24
27
33
37


VI++
Sample (n=4)
partial detection:
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_rel (dB)
30
20
10
0
-10
-20
-30
-40
-50
3
7
10
13
16
19
23
29
33
36


VI++
M1 (XII)
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
Lrel (dB)

VI++

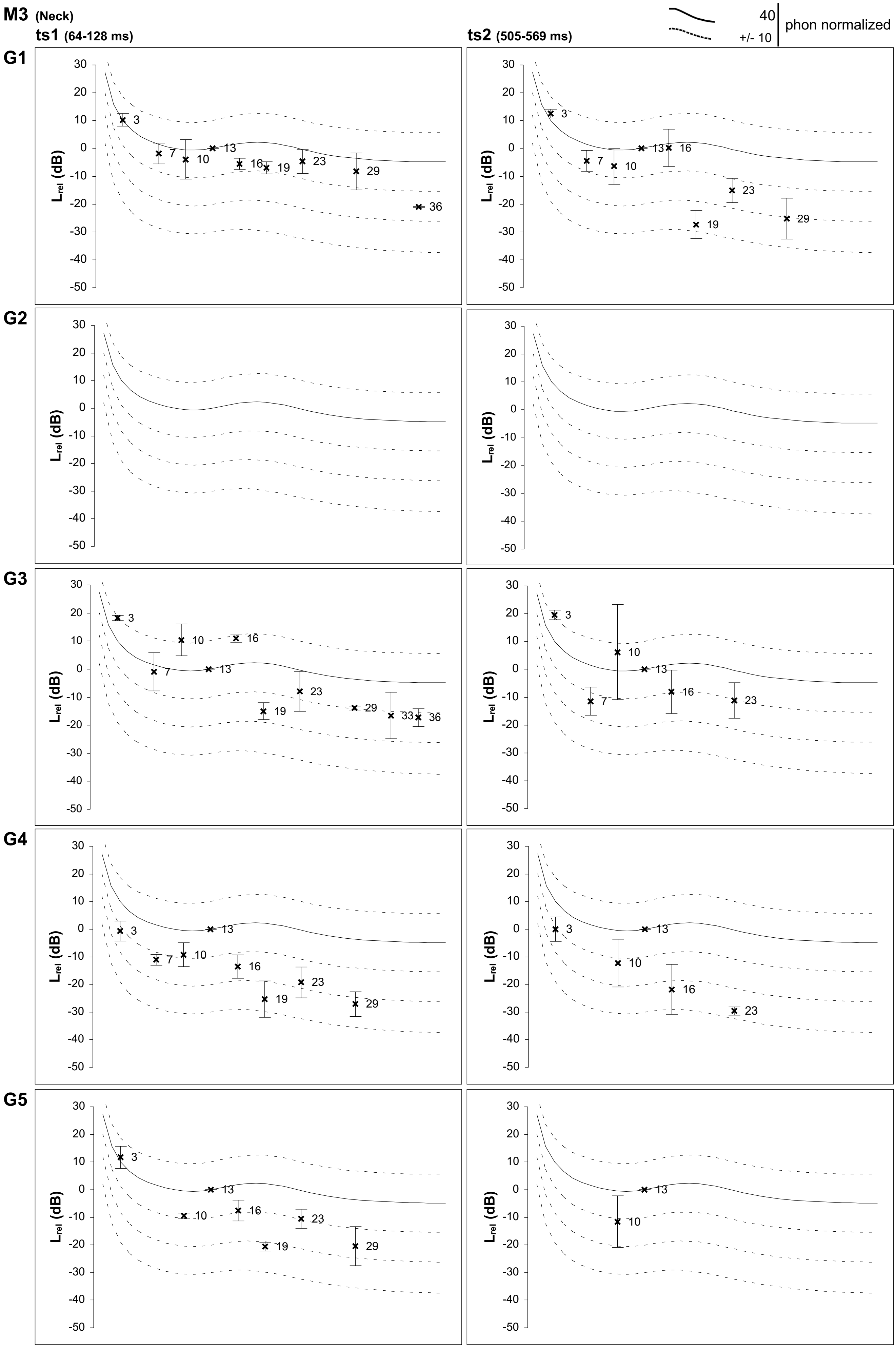
M2 (Sound hole)

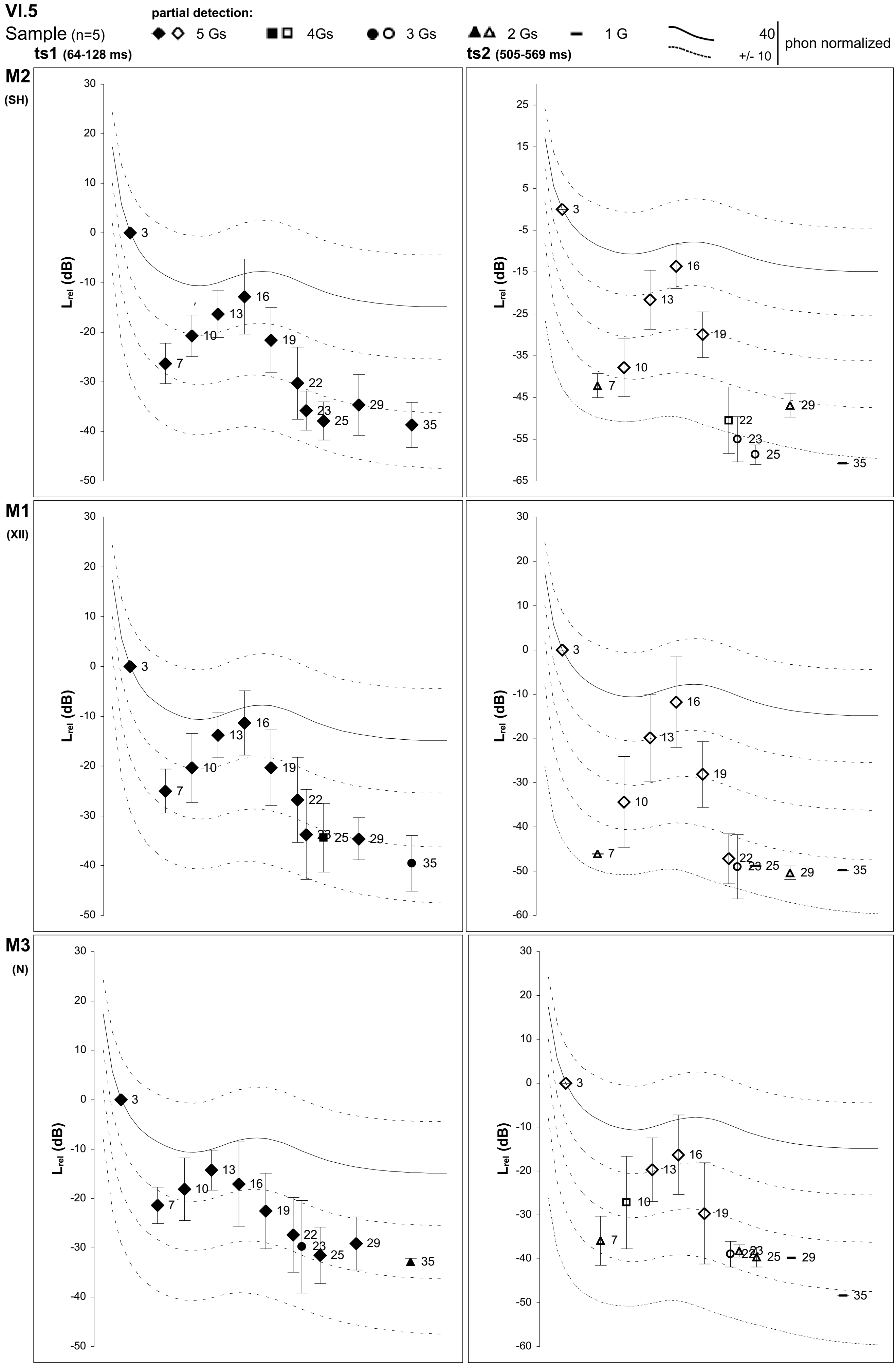


VI++

M3 (Neck)

ts1 (64-128 ms) **ts2** (505-569 ms)




VI.5
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_{rel} (dB)

VI.5

M1 (XII)

ts1 (64-128 ms) **ts2** (505-569 ms)

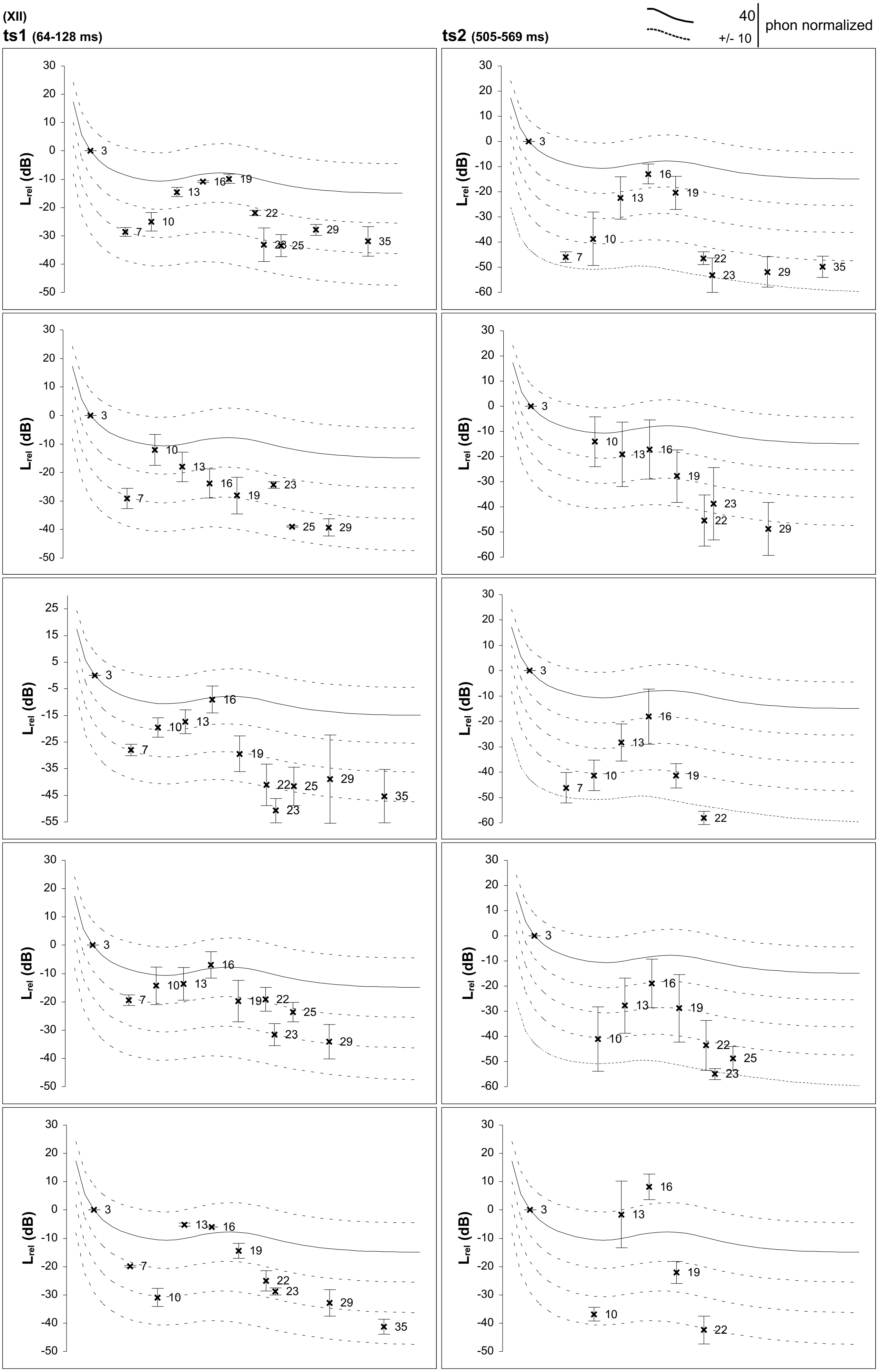
G1

G2

G3

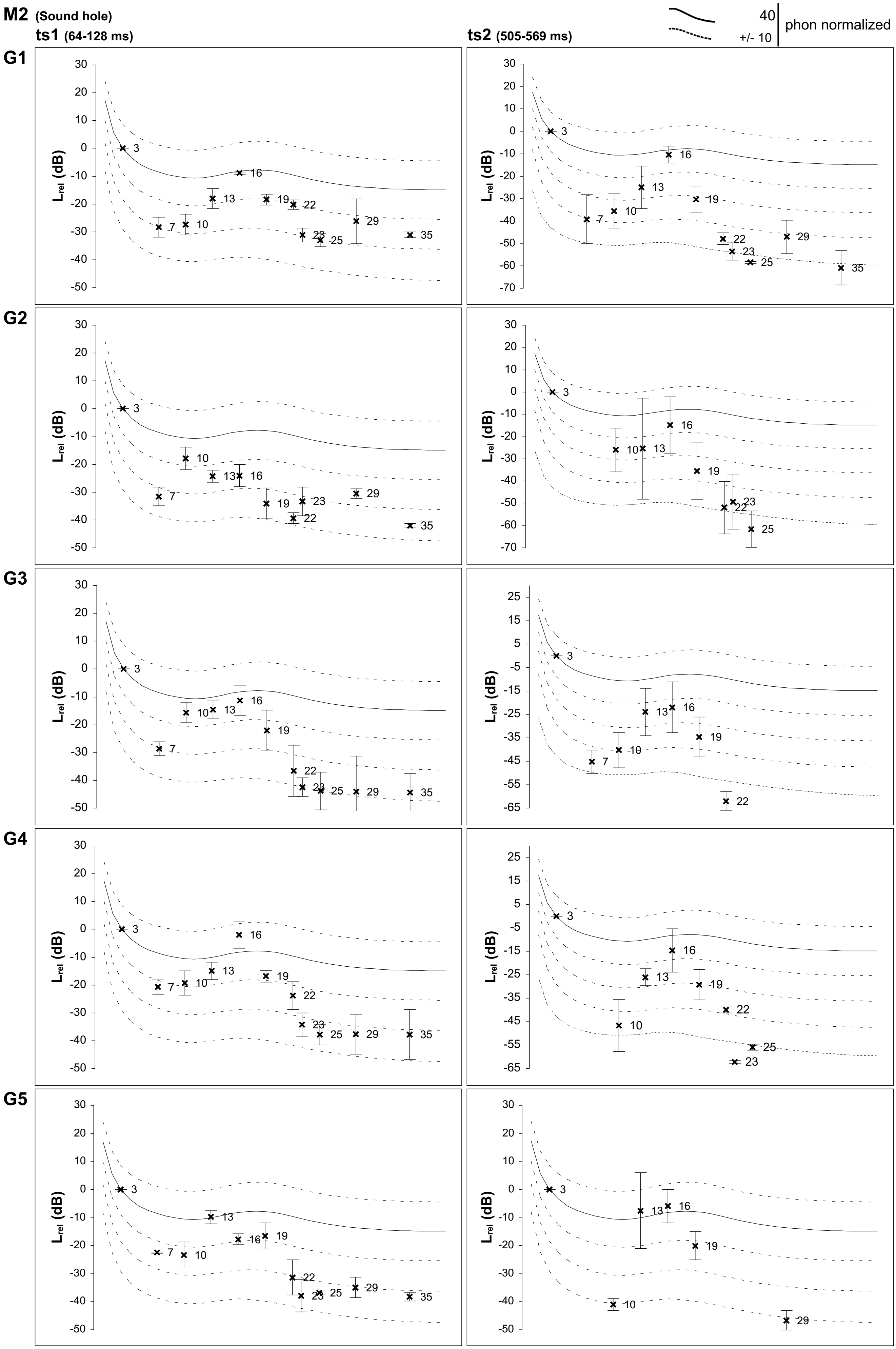
G4

G5



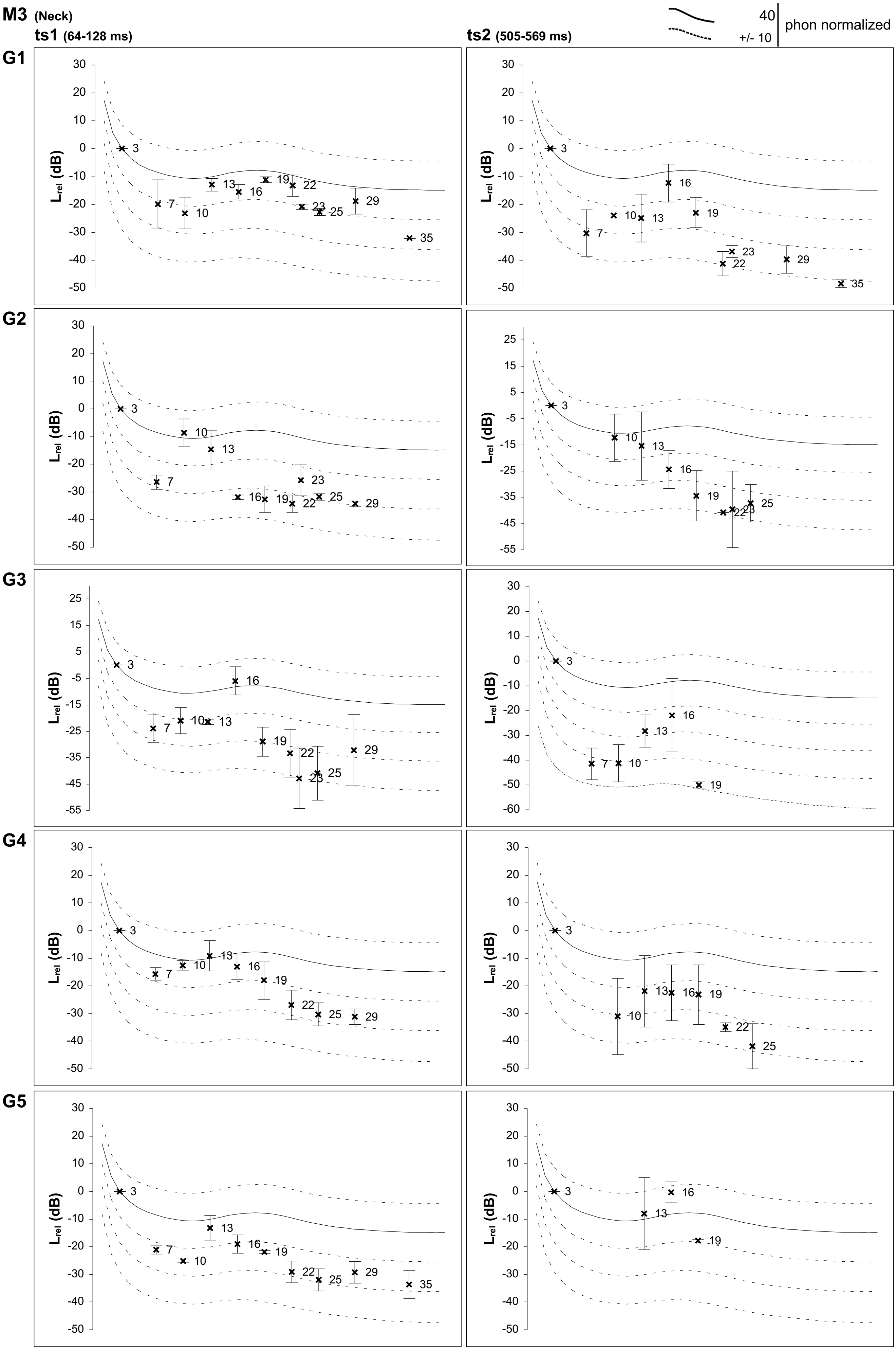
VI.5

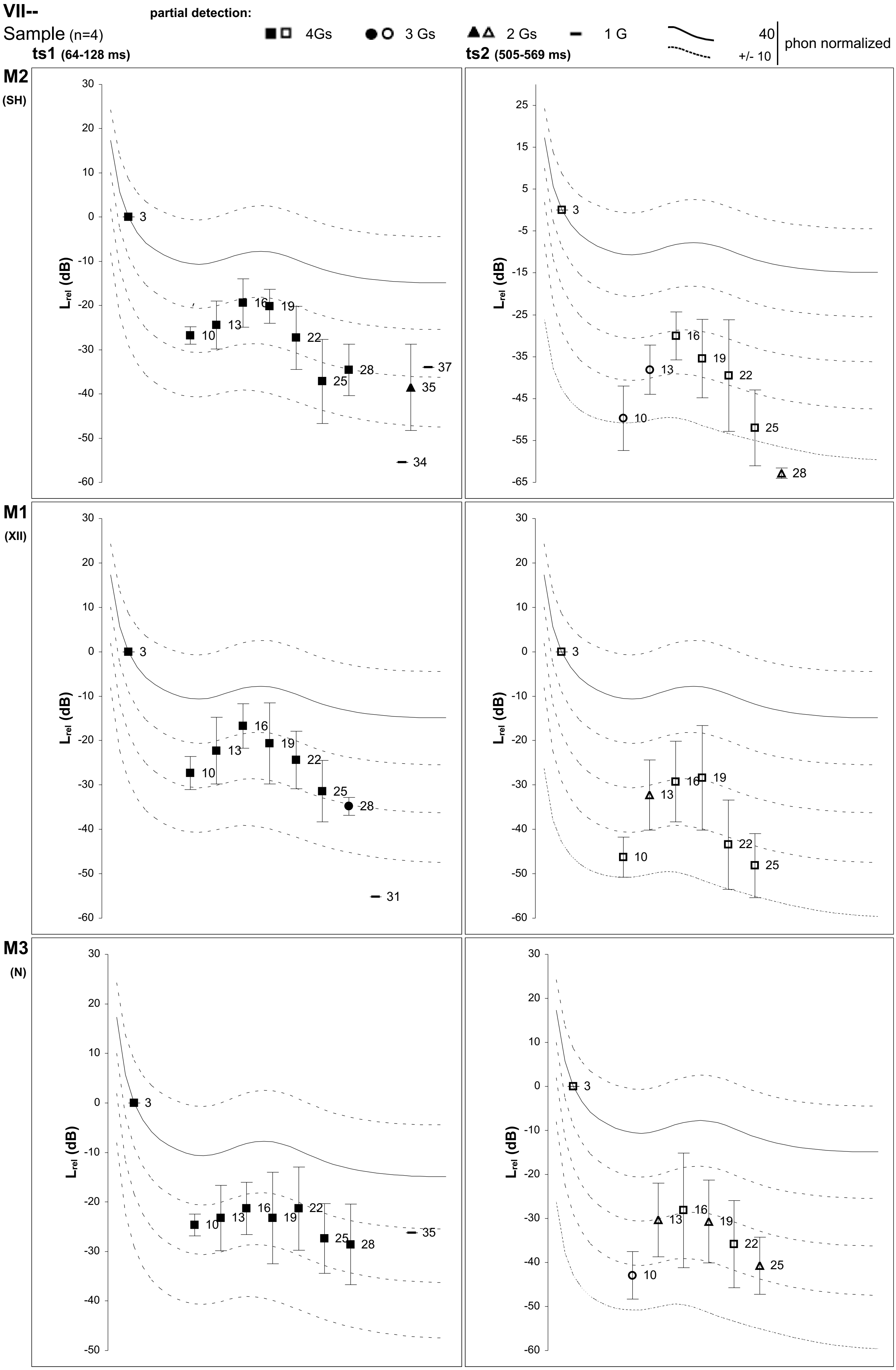
M2 (Sound hole)



VI.5

M3 (Neck)


ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
L_{rel} (dB)



VII--
Sample (n=4)
partial detection:
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
Lrel (dB)

VII--

M1 (XII)

ts1 (64-128 ms) | **ts2** (505-569 ms)

40 — phon normalized

+/- 10

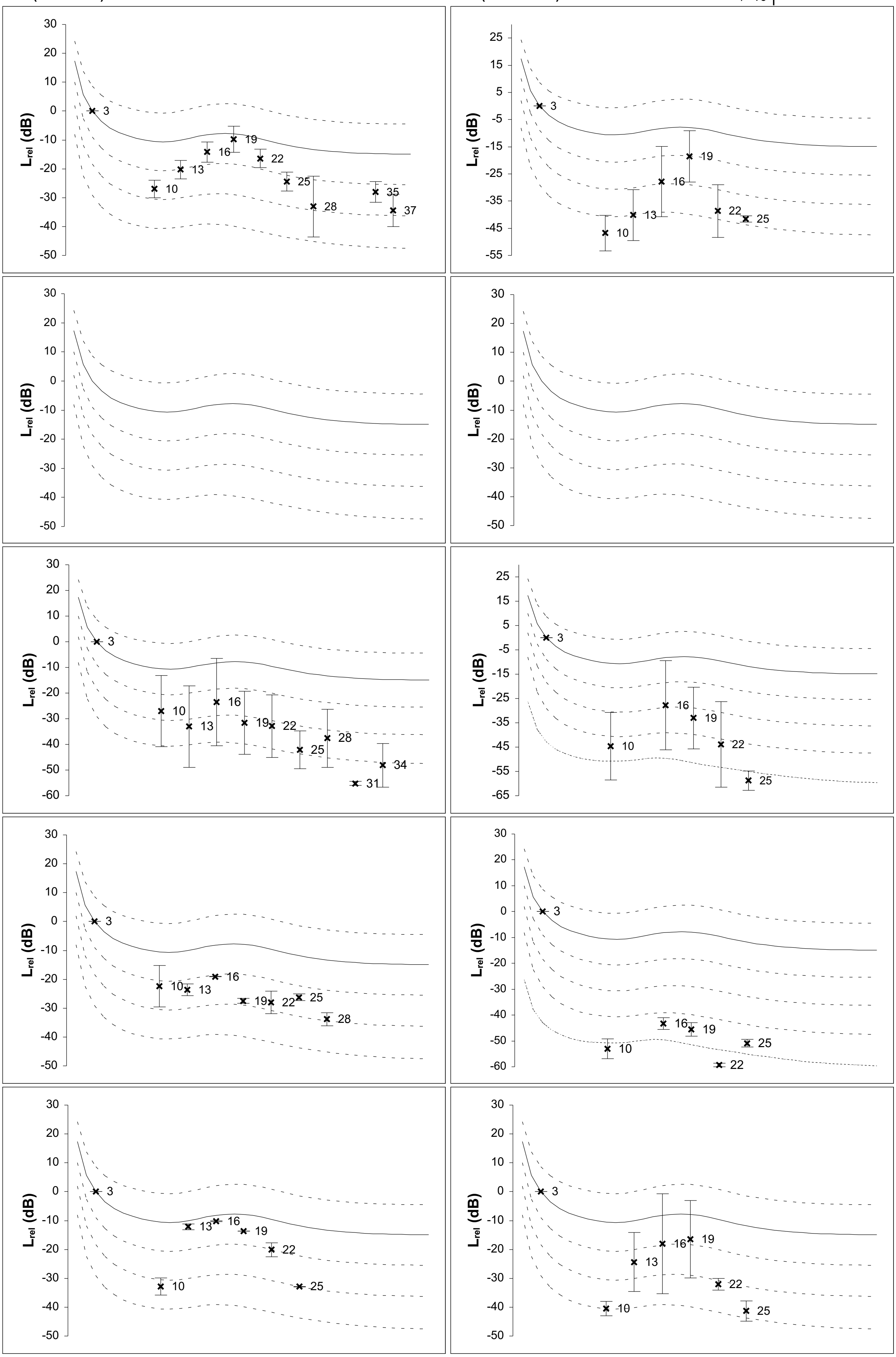
G1

G2

G3

G4 (2Ts)

G5



VII--

M2 (Sound hole)

ts1 (64-128 ms) **ts2** (505-569 ms)

40 | +/- 10 | phon normalized

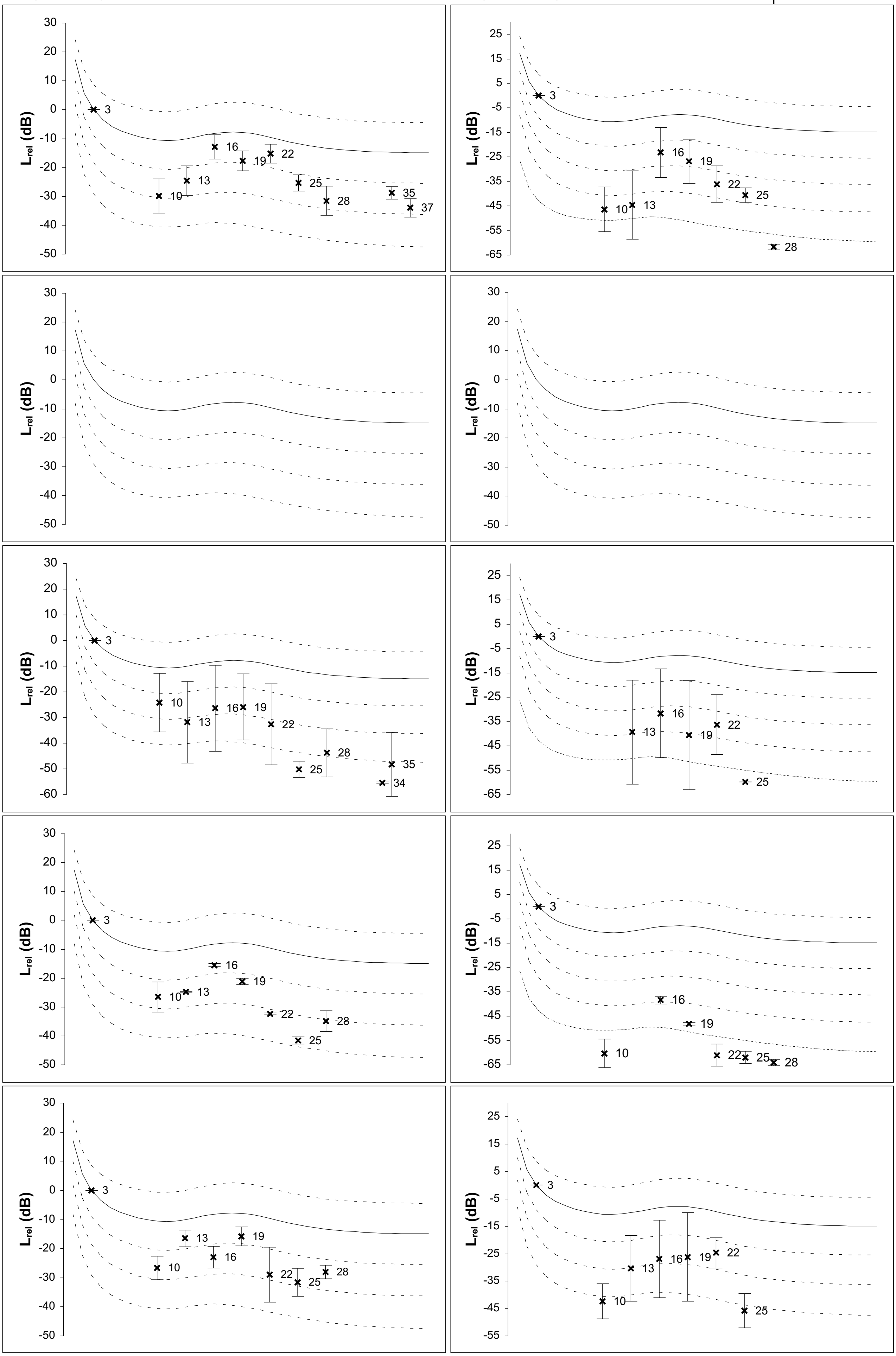
G1

G2

G3

G4 (2Ts)

G5



VII--

M3 (Neck)

40 — +/- 10 — phon normalized

ts1 (64-128 ms) **ts2** (505-569 ms)

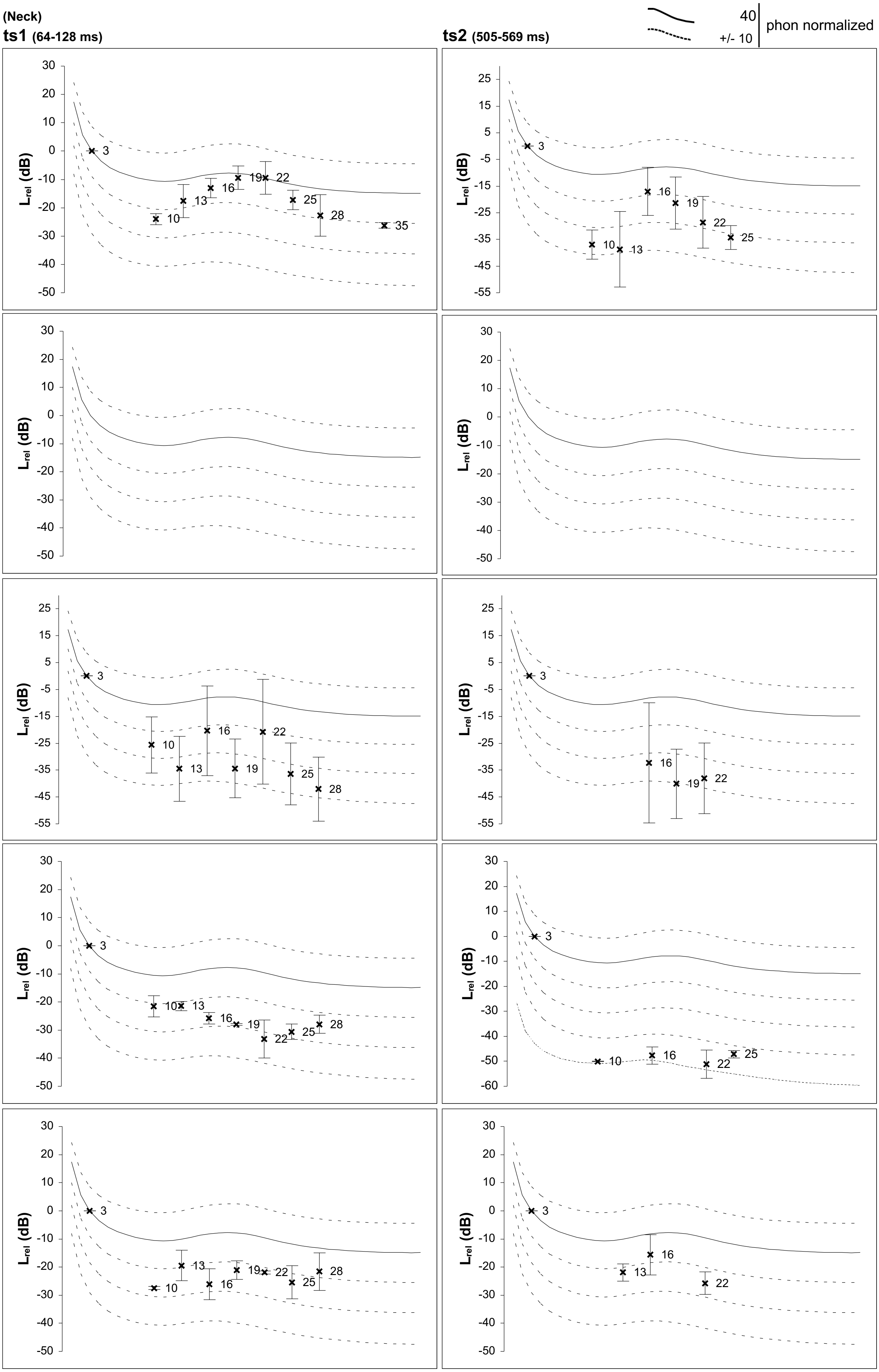
G1

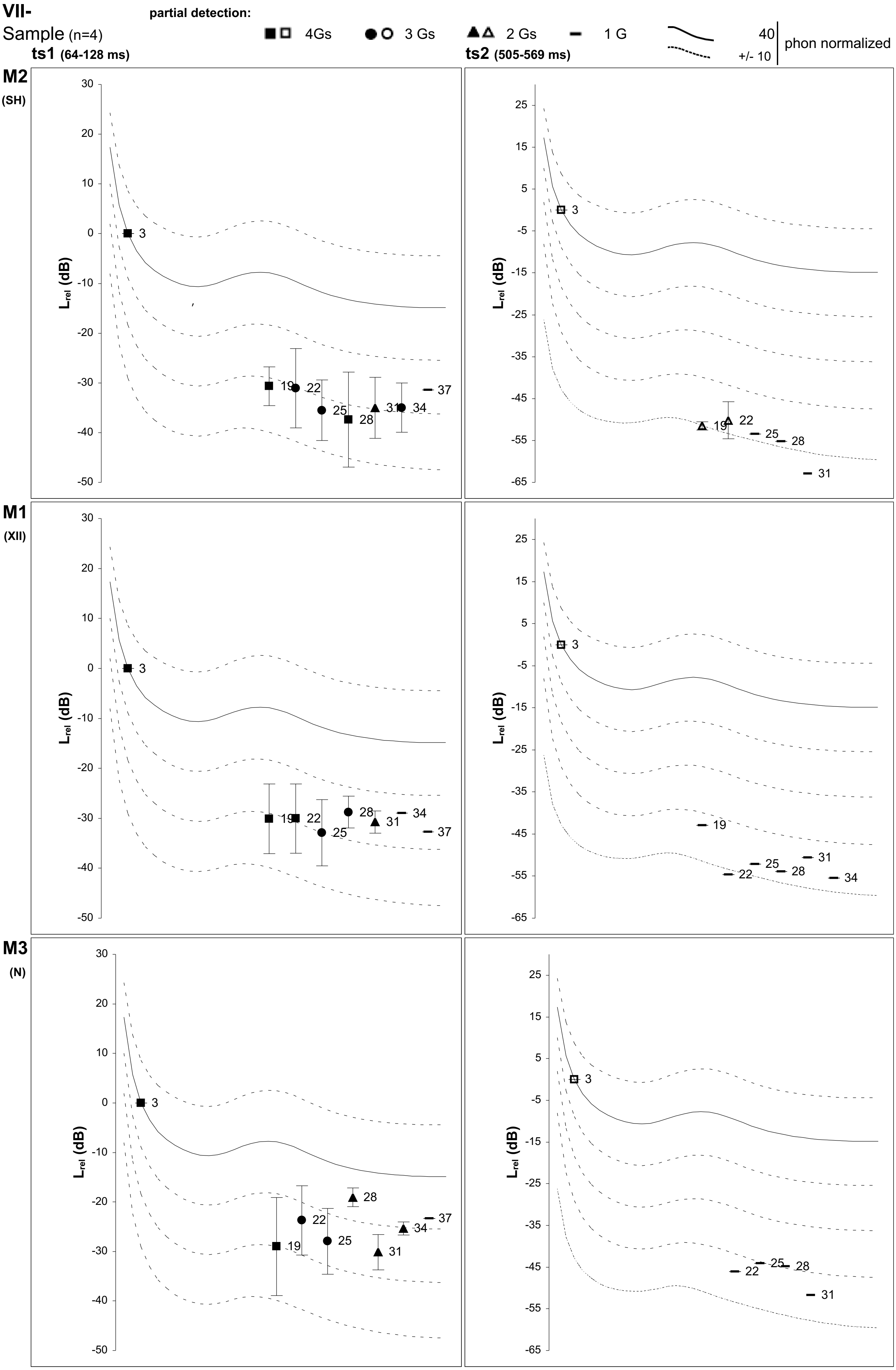
G2

G3

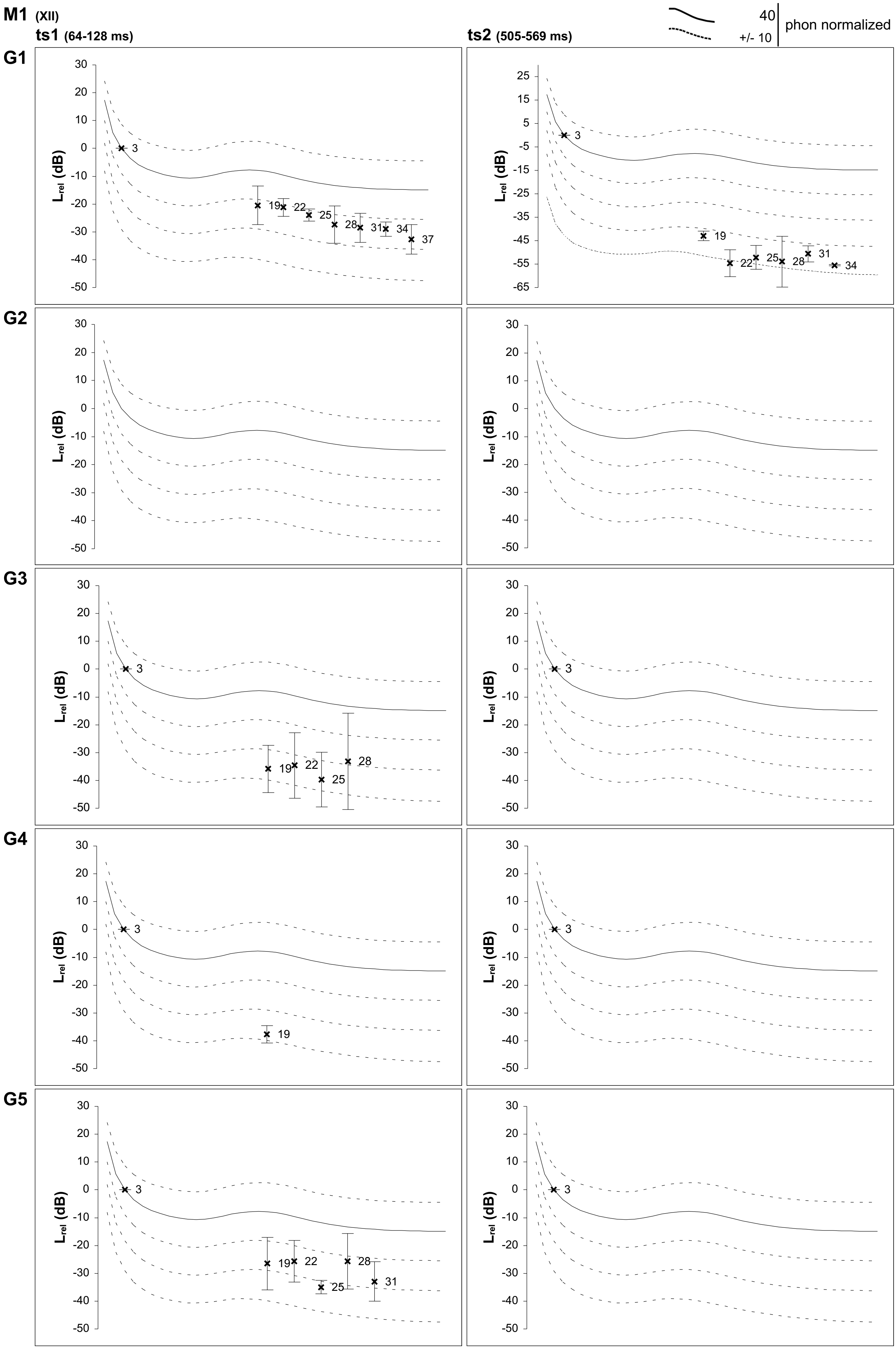
G4 (2Ts)

G5




VII-
Sample (n=4)
partial detection:
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_rel (dB)

VII-
M1 (XII)



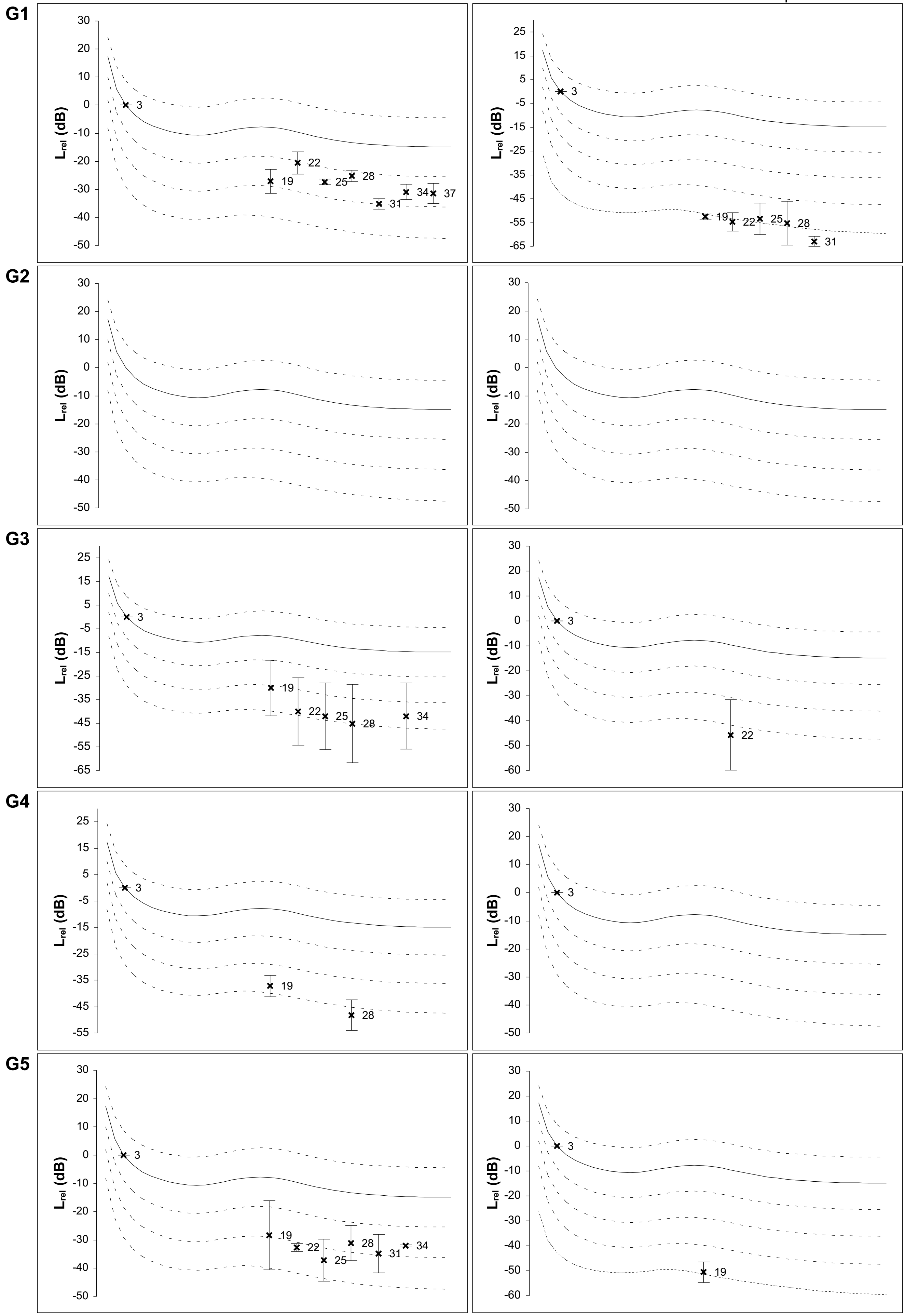
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
L_rel (dB)

VII-

M2 **(Sound hole)**

ts1 **(64-128 ms)** **ts2** **(505-569 ms)**

40 | phon normalized
+/- 10 |

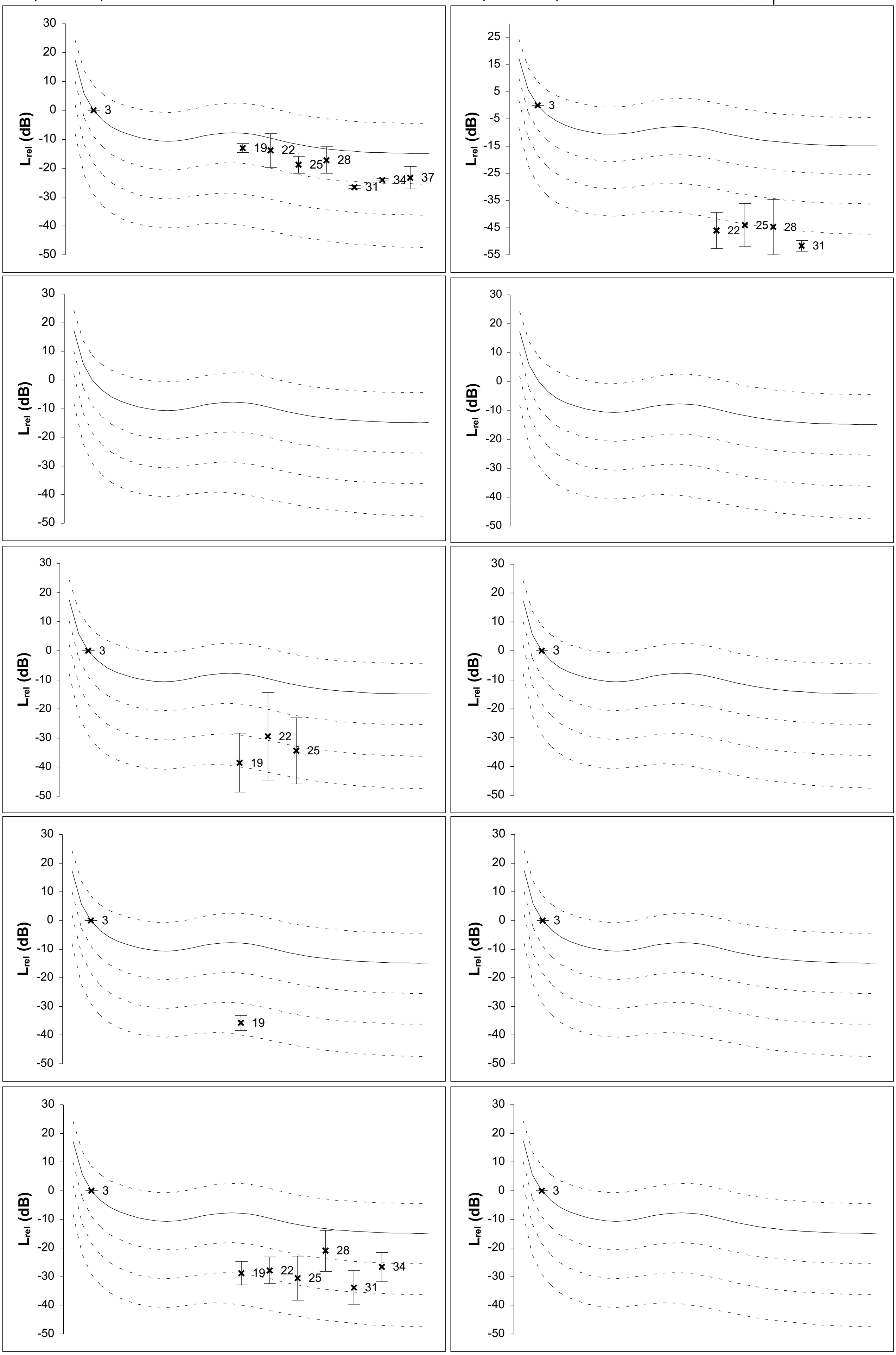


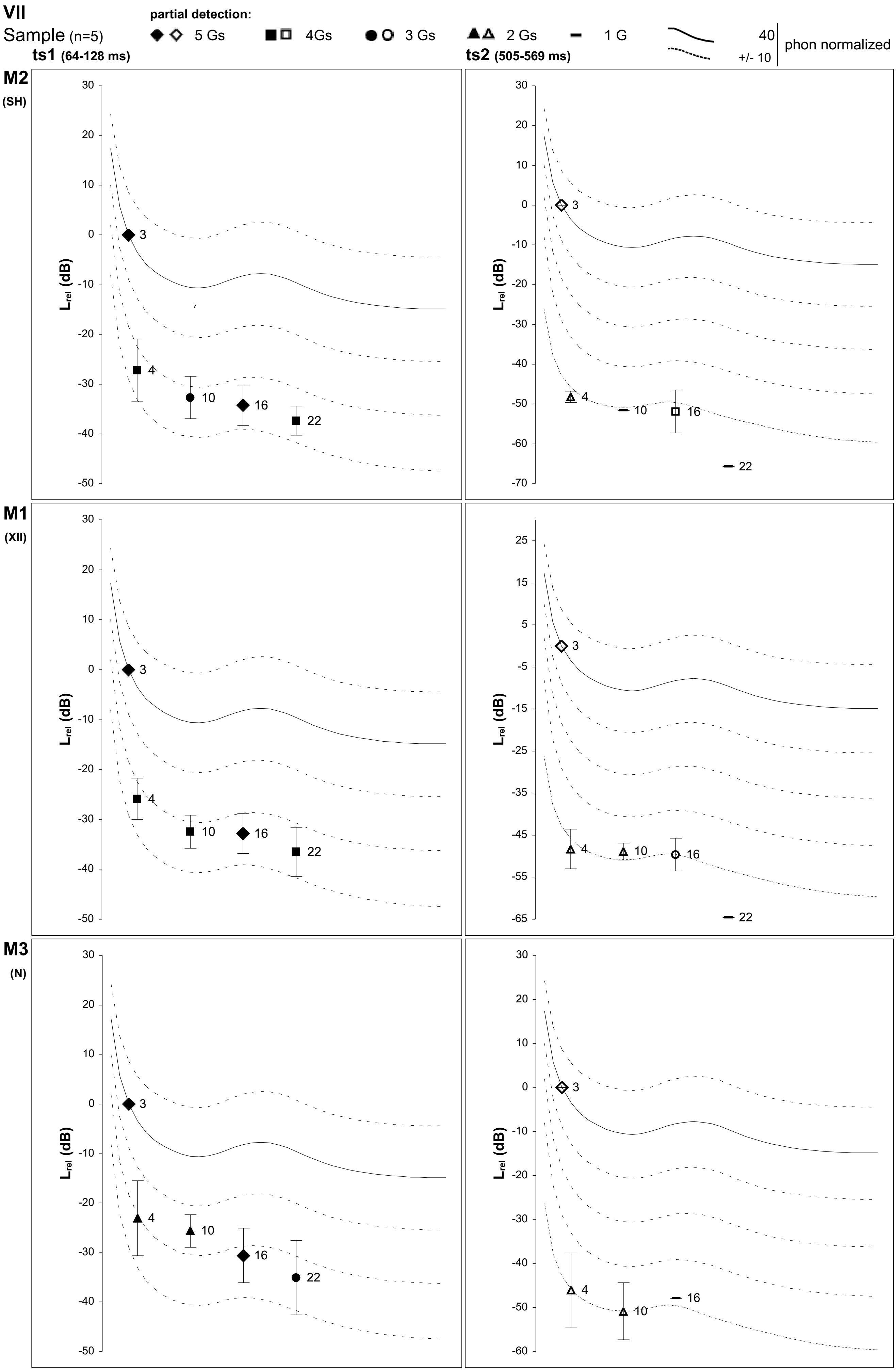
VII-
M3 (Neck)

ts1 (64-128 ms) **ts2** (505-569 ms)

40 | phon normalized
+/- 10 |

G1
G2
G3
G4
G5



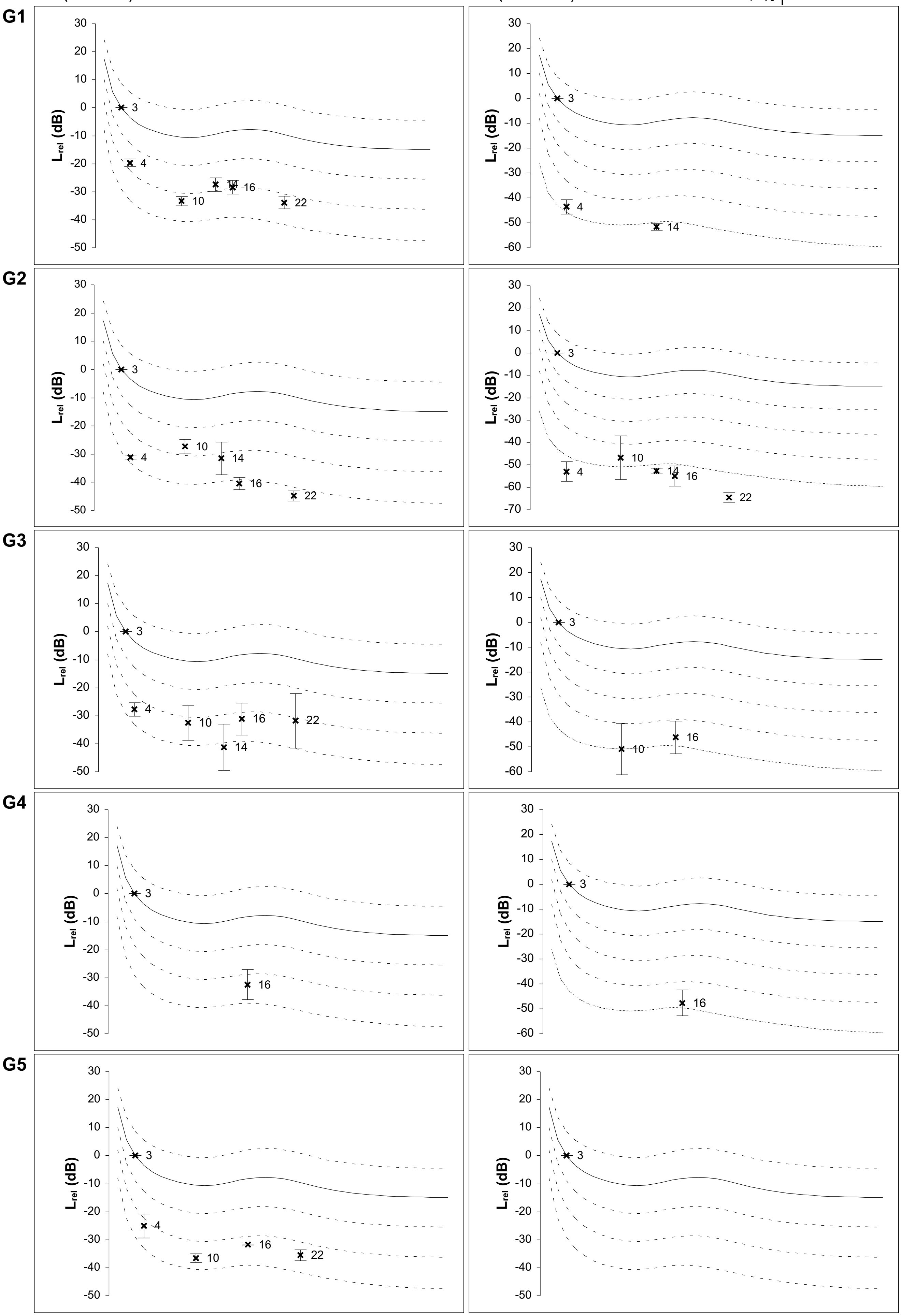

VII
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_rel (dB)

VII

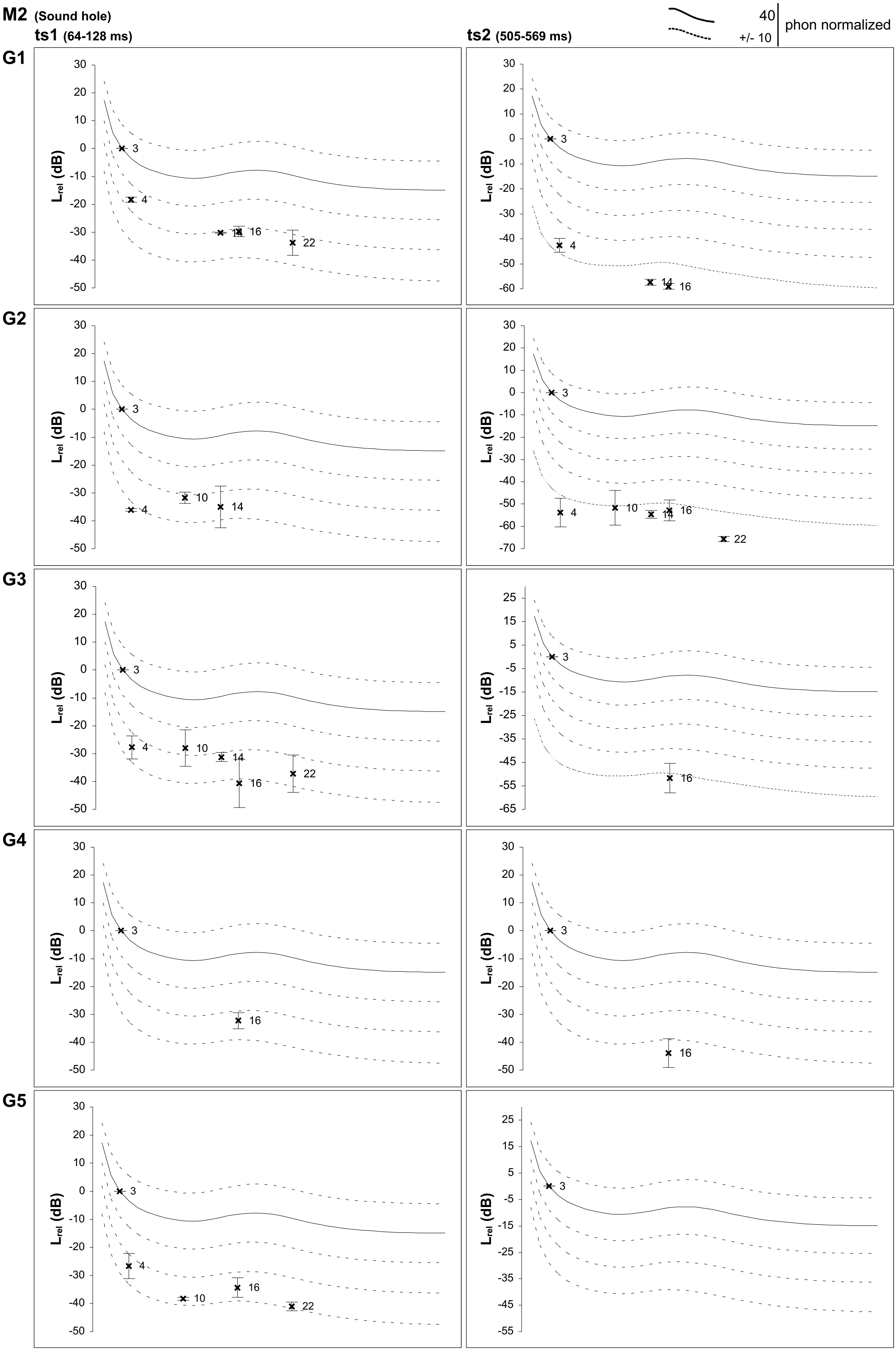
M1 (XII)

40 / +/- 10 phon normalized

ts1 (64-128 ms) **ts2** (505-569 ms)

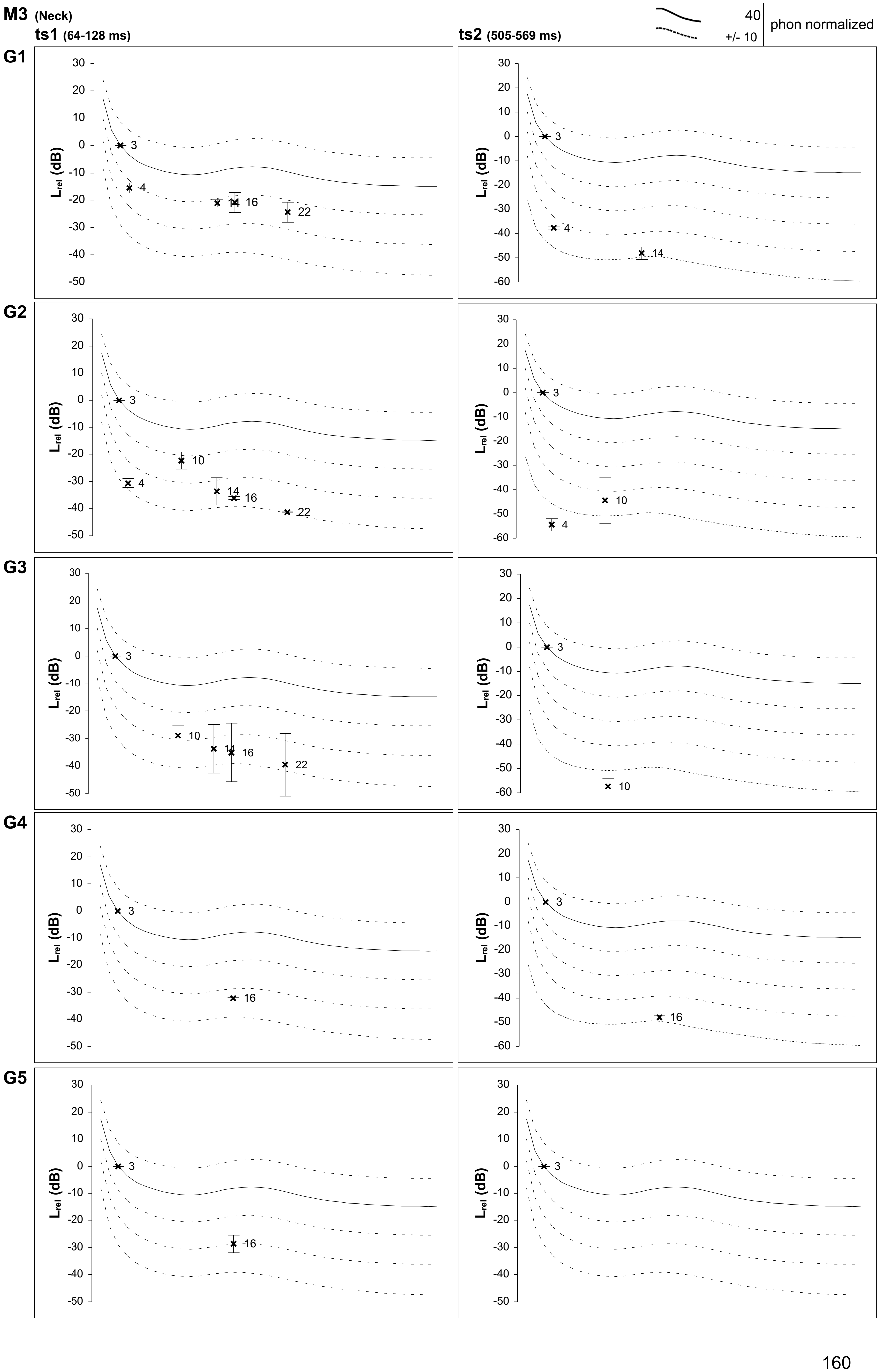


VII


M2 (Sound hole)
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
Lrel (dB)

VII

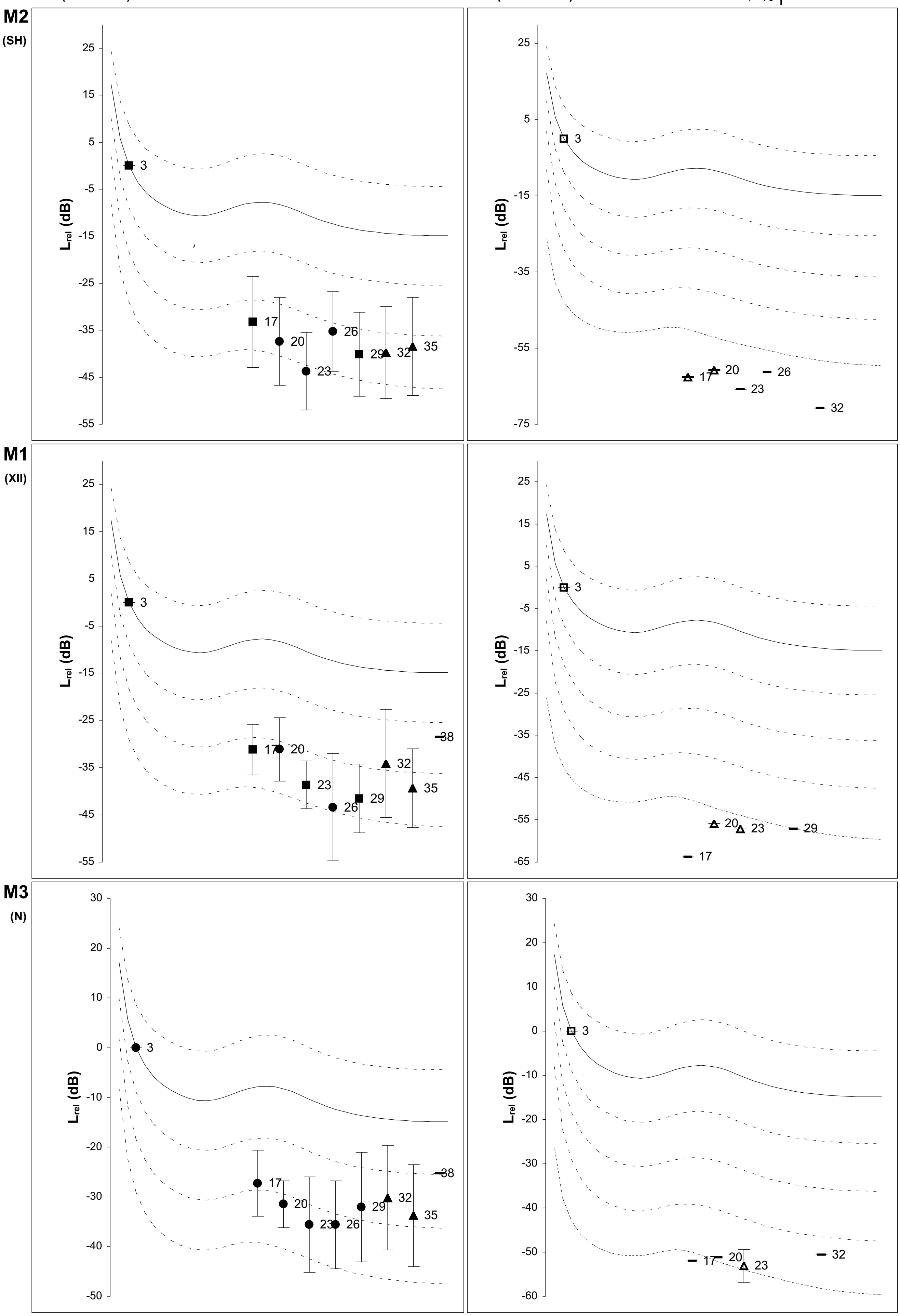
M3 (Neck)



ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
L_{rel} (dB)

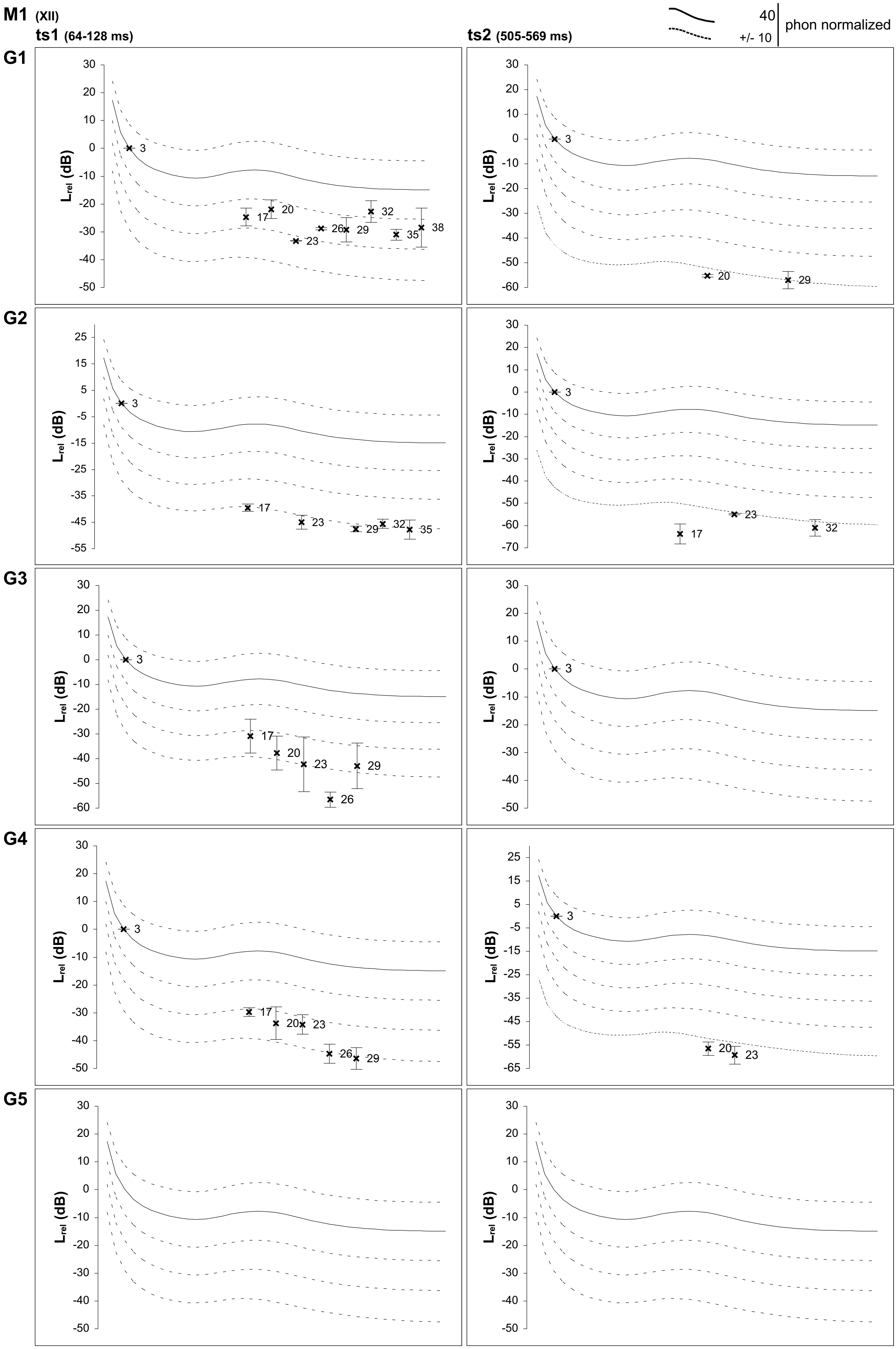
VII+ **partial detection:**

Sample (n=4) ■□ 4Gs ●○ 3 Gs ▲△ 2 Gs ▬ 1 G — 40 ---- +/- 10 phon normalized



VII+

M1 (XII)



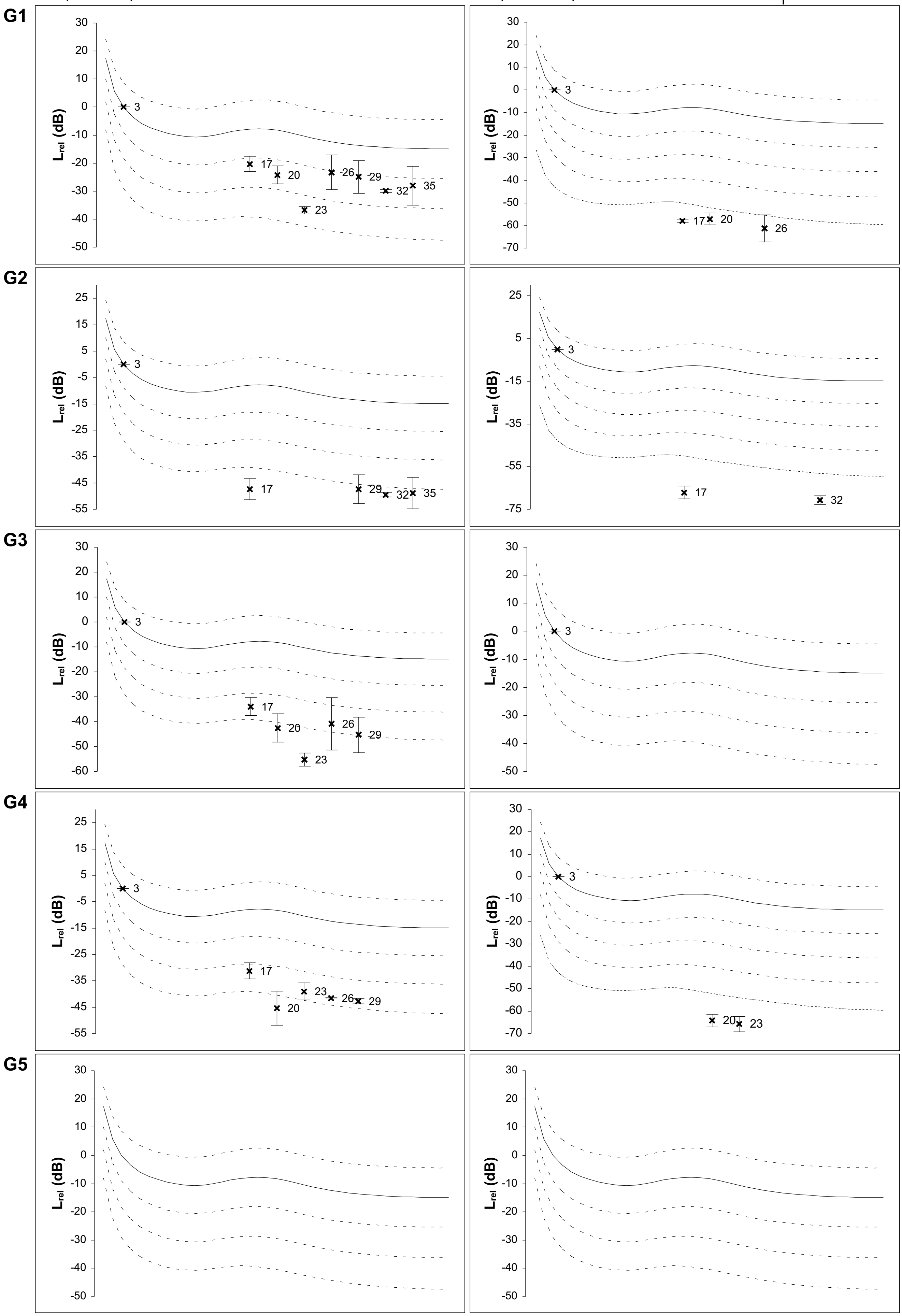
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
G1
G2
G3
G4
G5
L_{rel} (dB)

VII+

M2 (Sound hole)

ts1 (64-128 ms) **ts2** (505-569 ms)

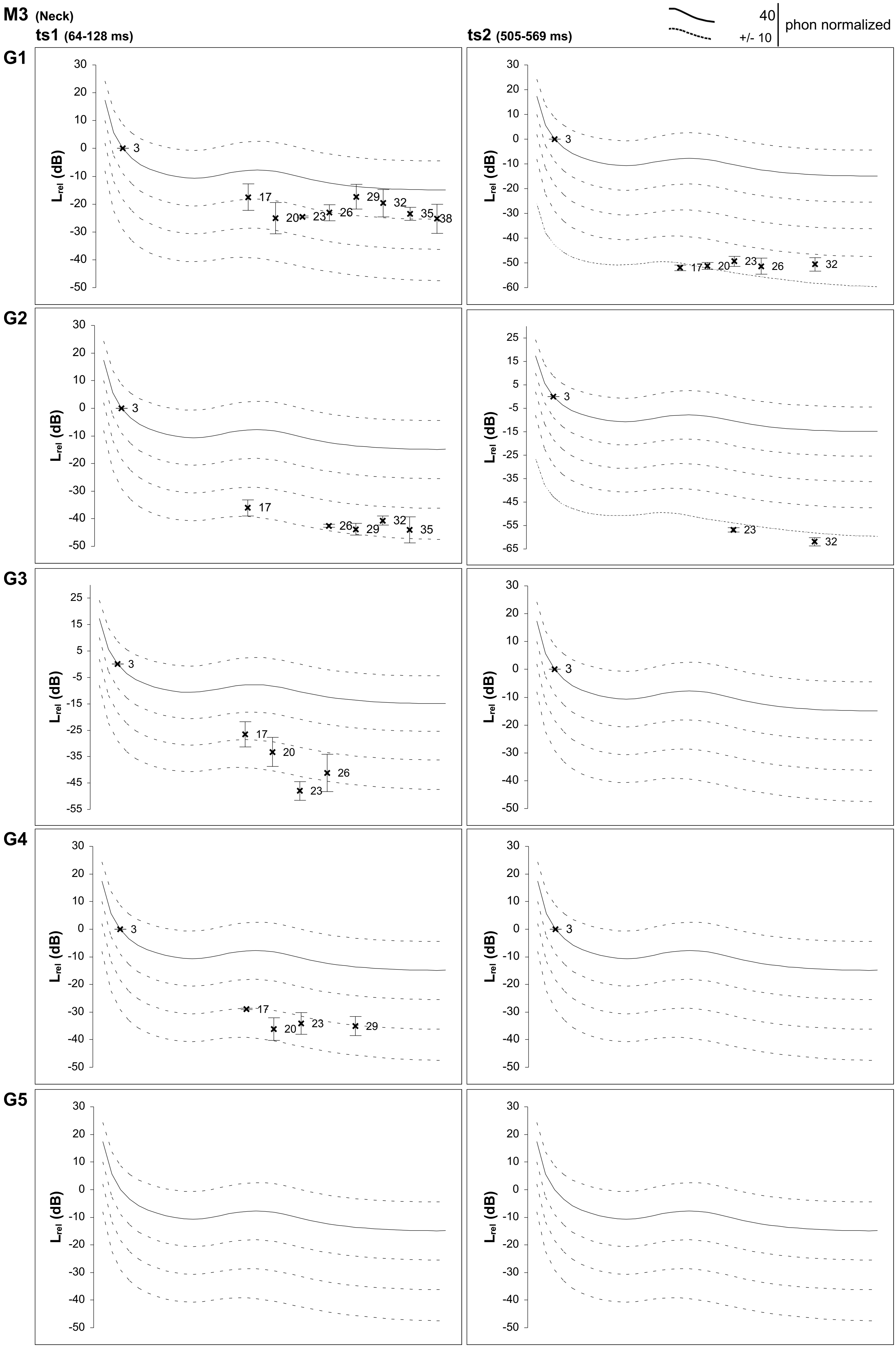
40 | phon normalized
+/- 10

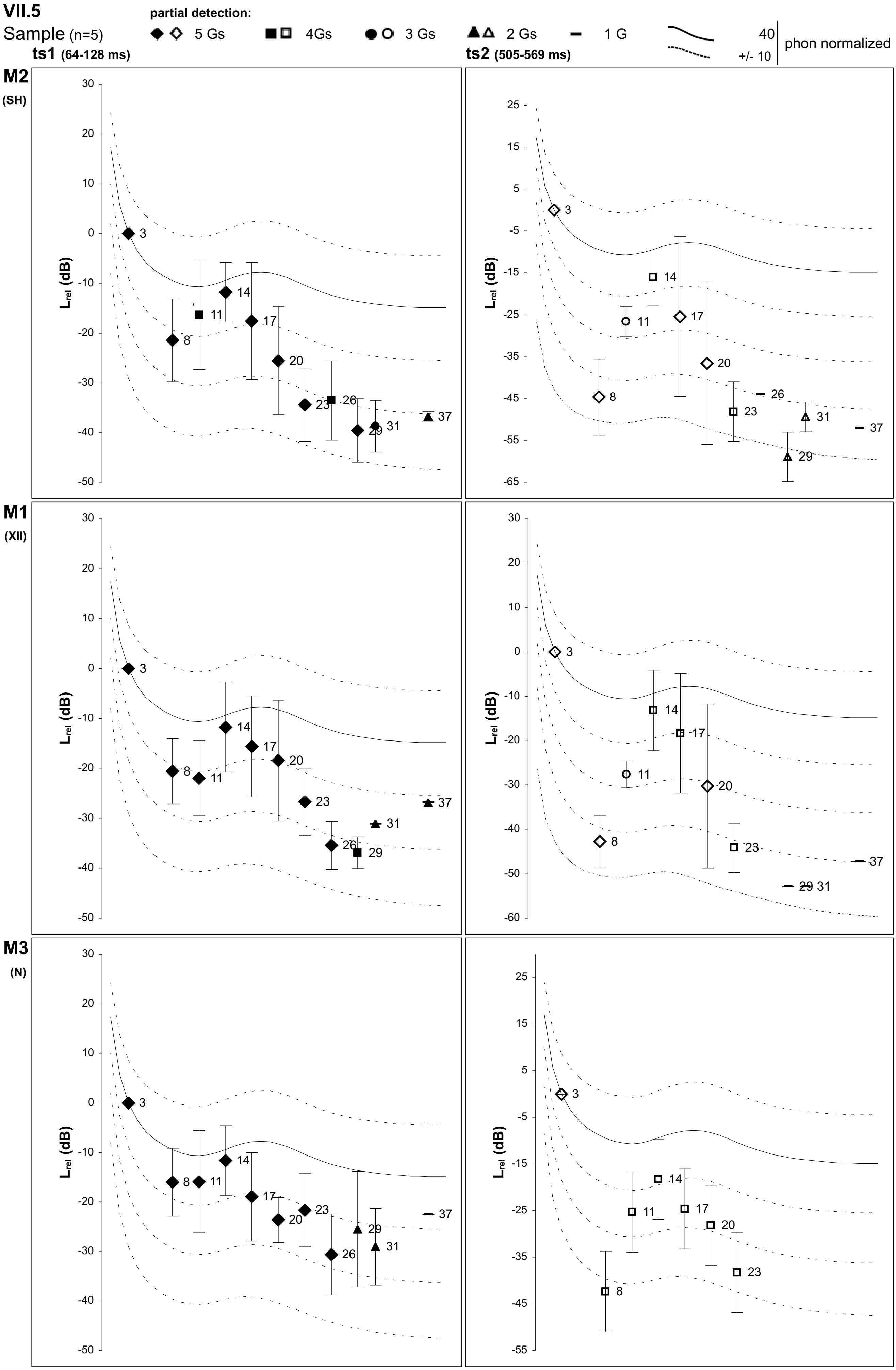


VII+

M3 (Neck)

ts1 (64-128 ms) **ts2** (505-569 ms)




VII.5
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_{rel} (dB)

VII.5

M1 (XII)

ts1 (64-128 ms) **ts2** (505-569 ms)

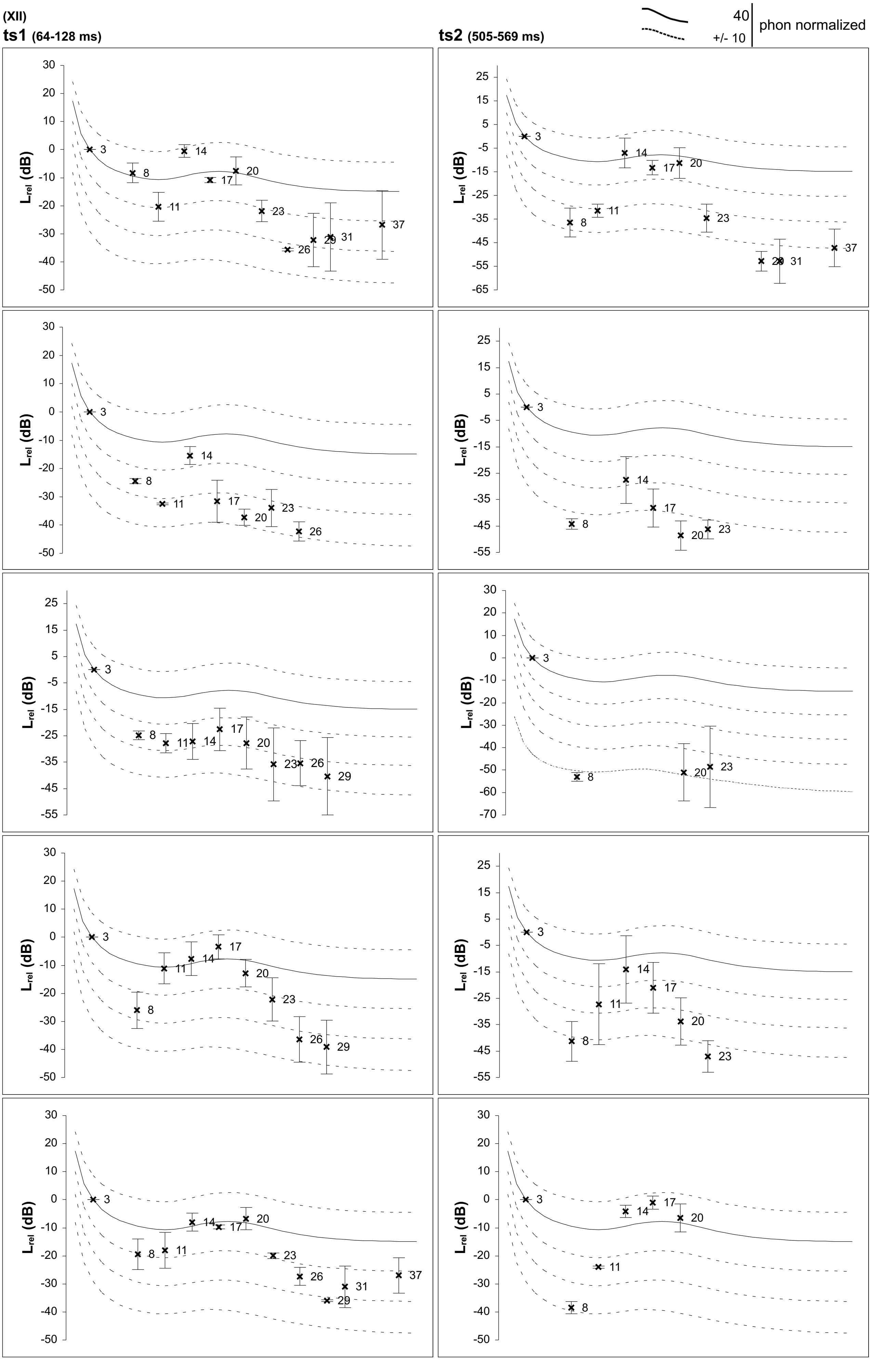
G1

G2

G3

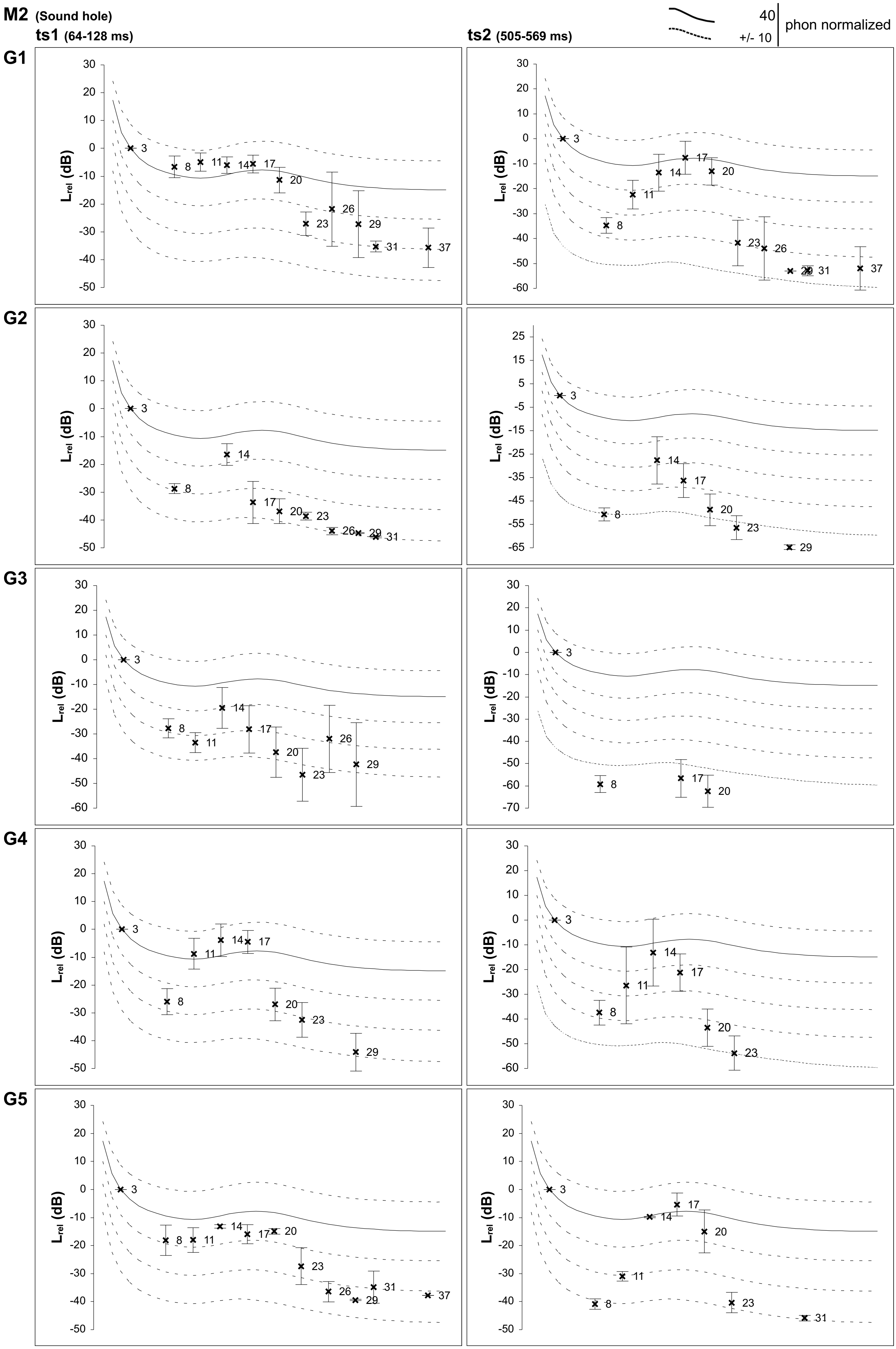
G4

G5



VII.5

M2 (Sound hole)

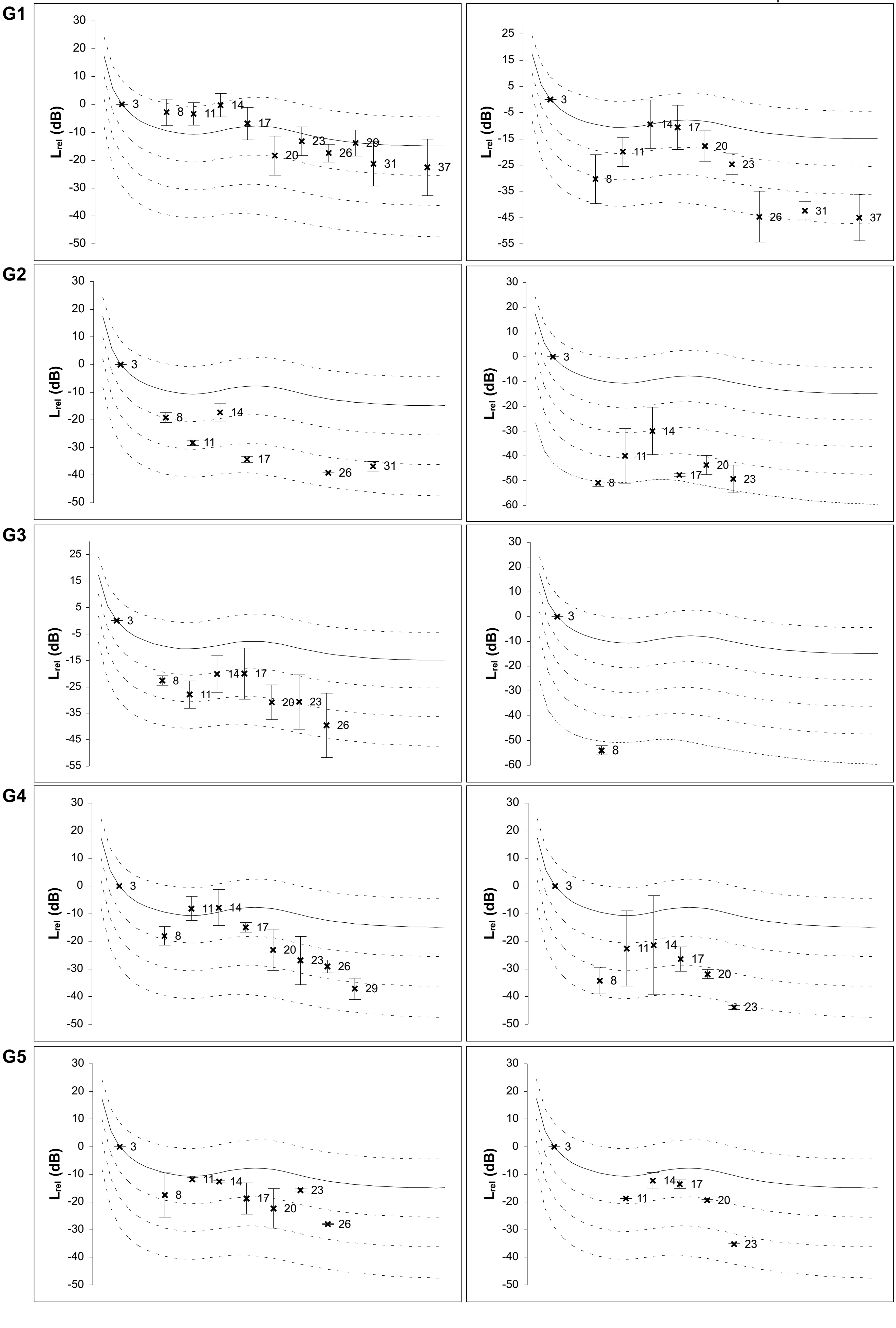


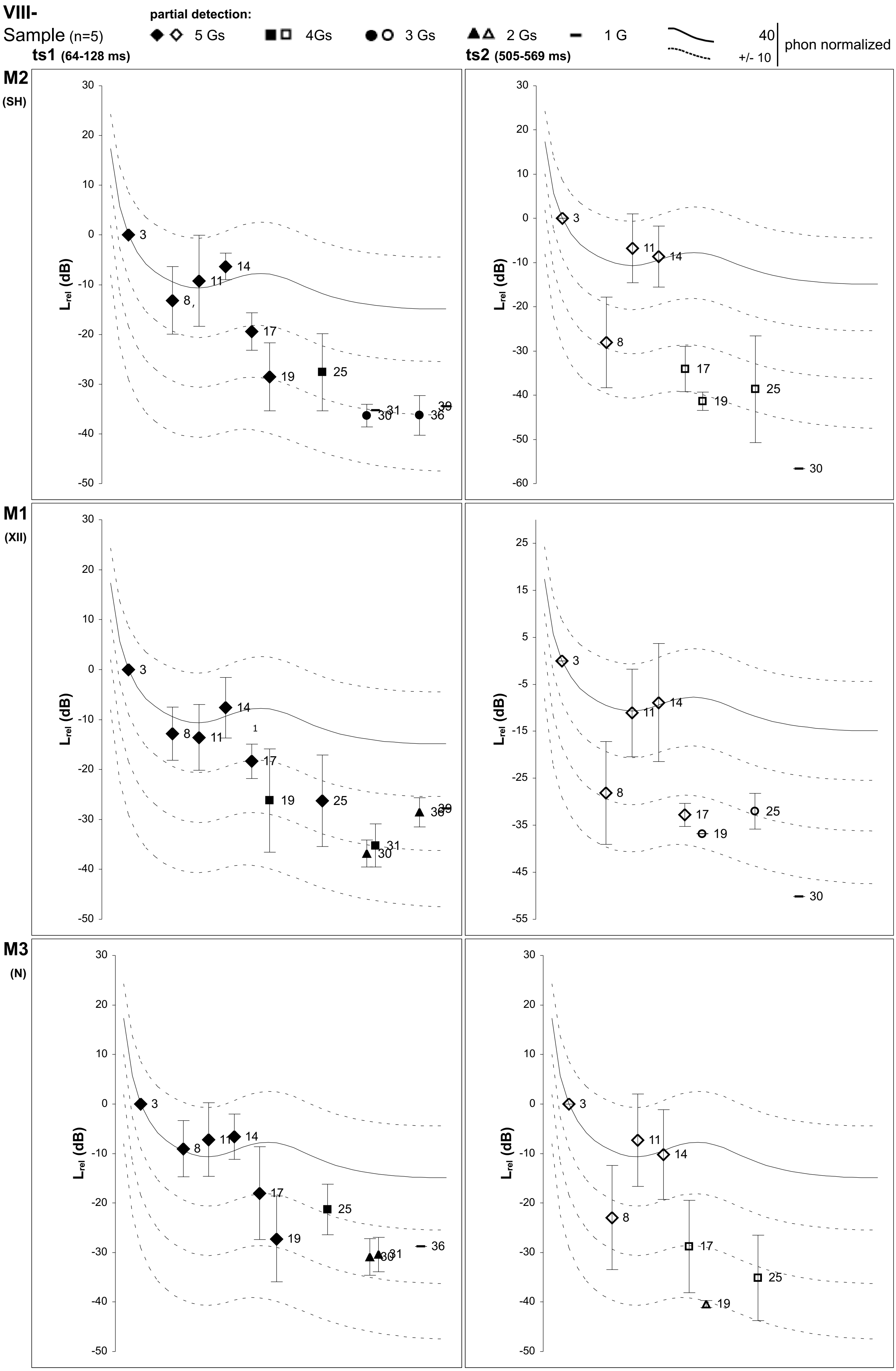
VII.5

M3 (Neck)

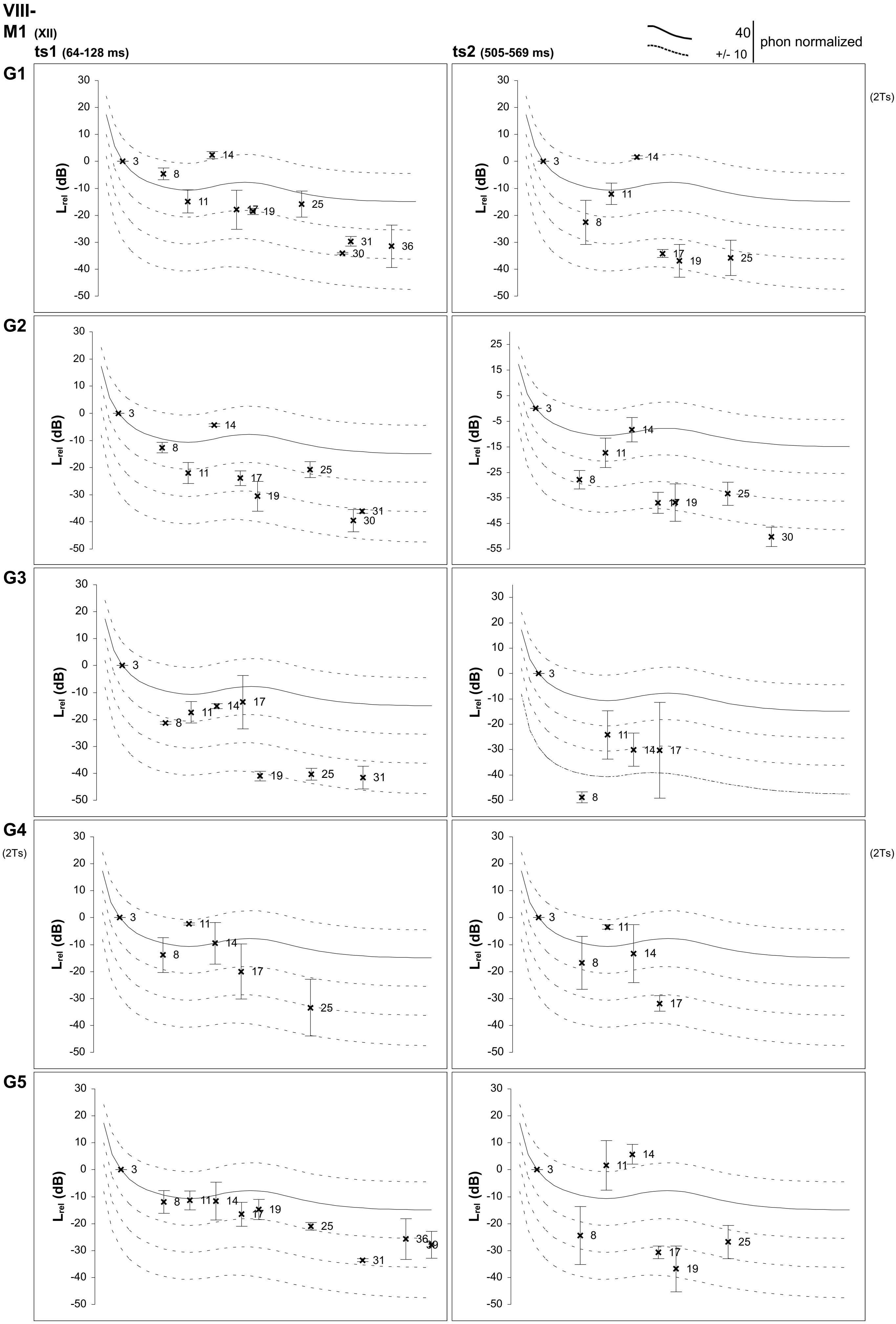
40 / +/- 10 — phon normalized

ts1 (64-128 ms) **ts2** (505-569 ms)





VIII-
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_rel (dB)


VIII-
M1 (XII)
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
(2Ts)
Lrel (dB)

VIII-

M2 **(Sound hole)**

40 | phon normalized
+/- 10

ts1 **(64-128 ms)** **ts2** **(505-569 ms)**

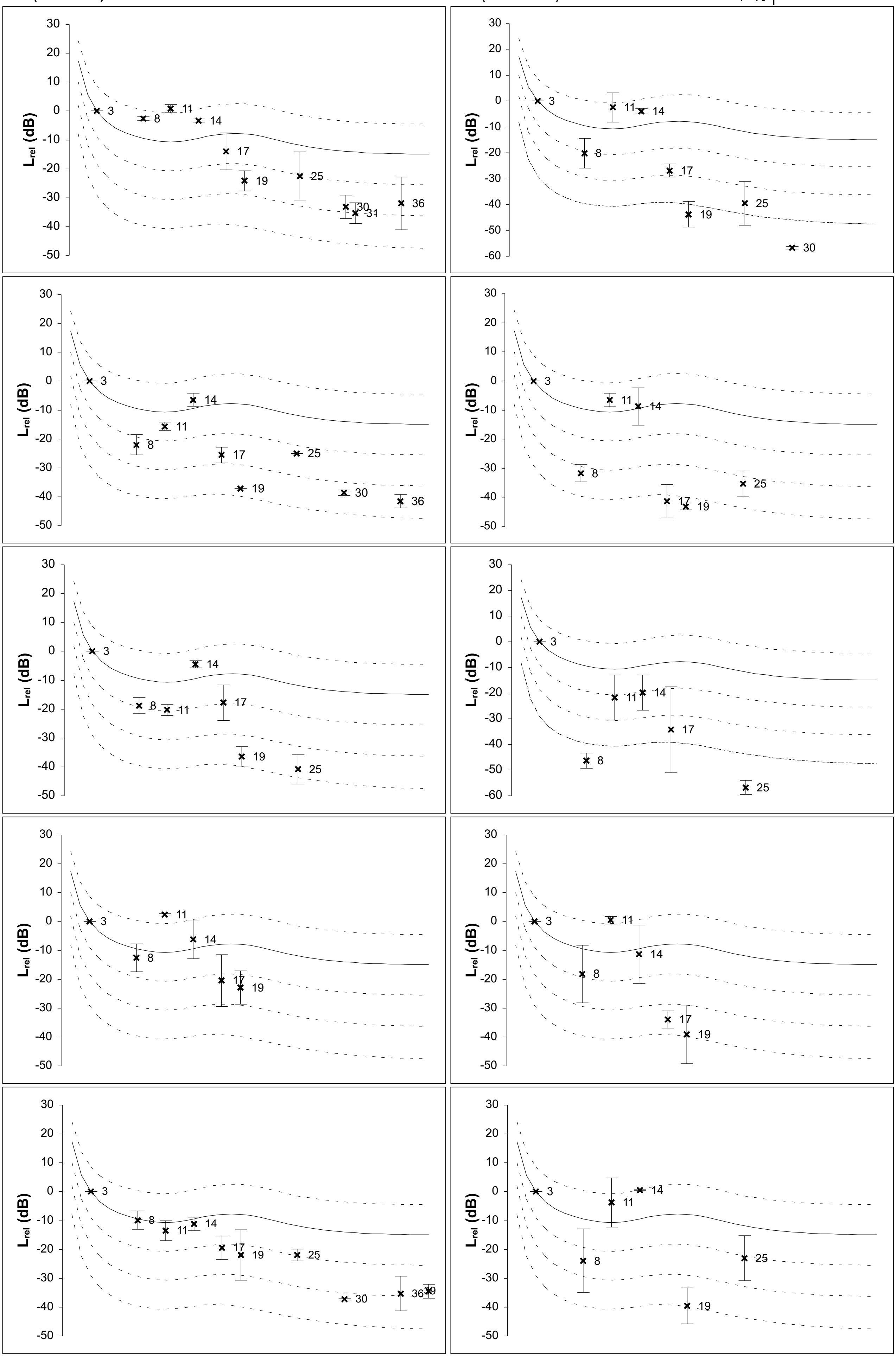
G1 (2Ts)

G2

G3

G4 (2Ts) (2Ts)

G5



VIII-
M3 **(Neck)**

ts1 **(64-128 ms)** **ts2** **(505-569 ms)**

40 +/- 10 phon normalized

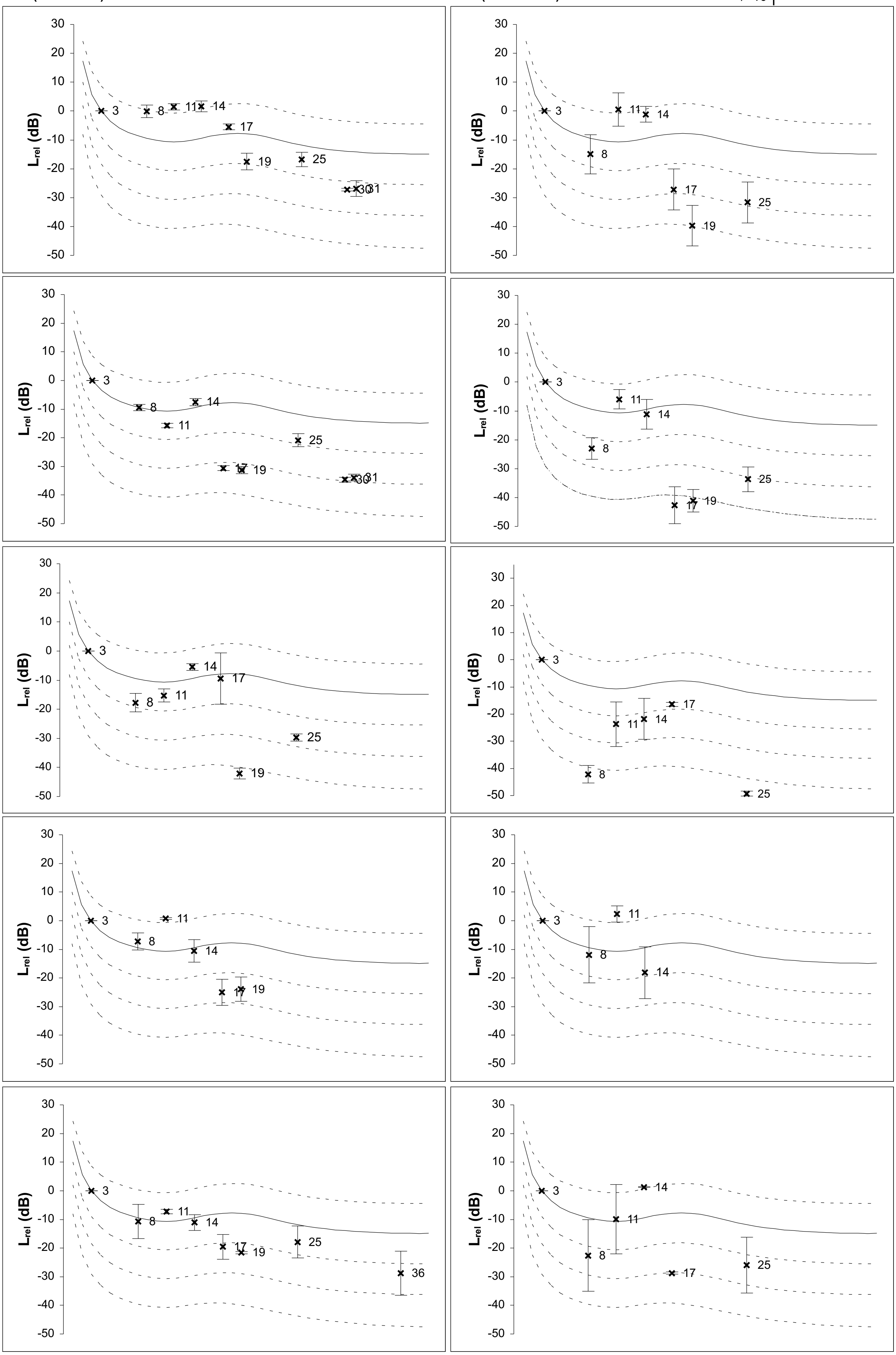
G1 (2Ts)

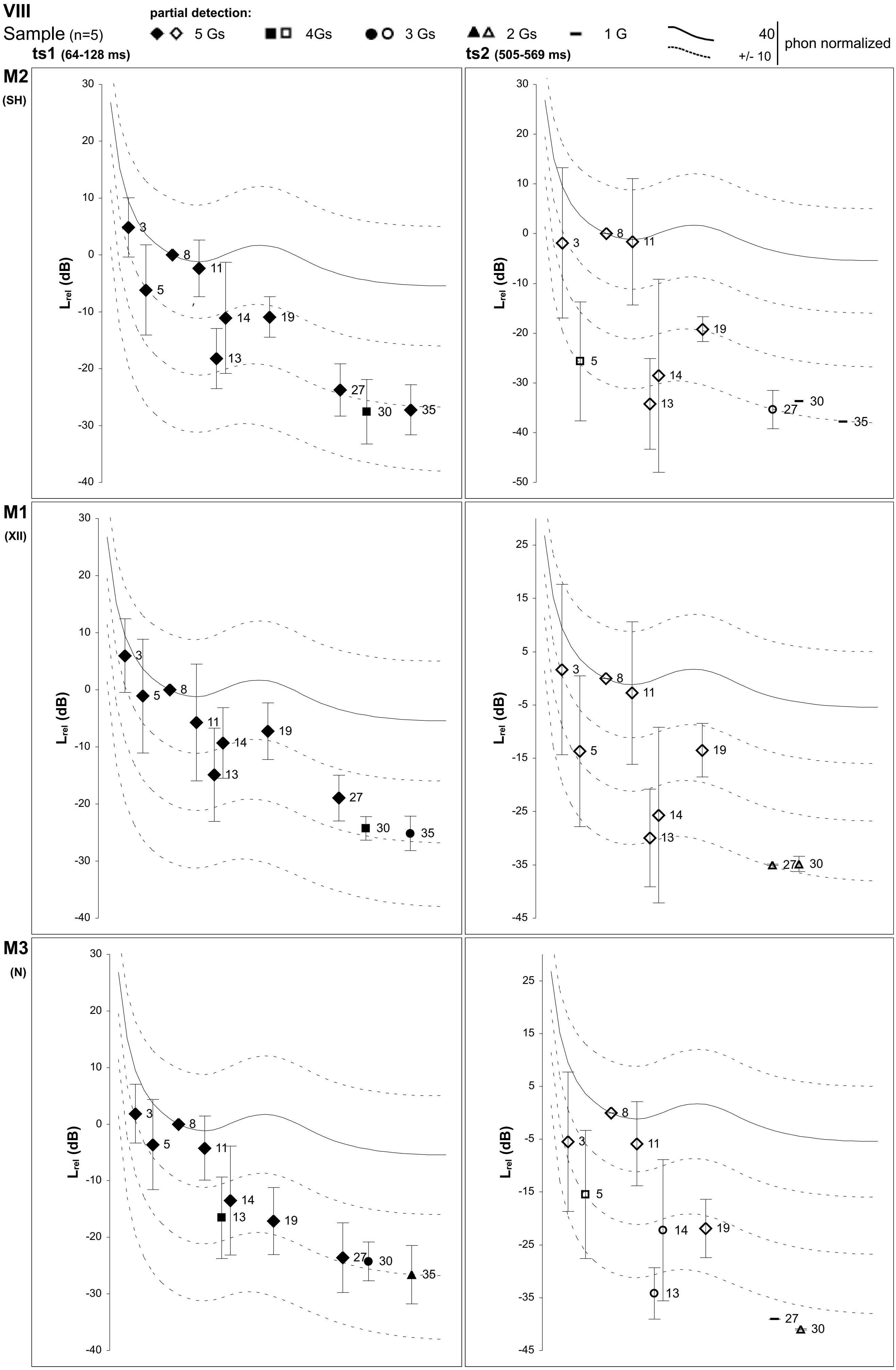
G2

G3

G4 (2Ts) (2Ts)

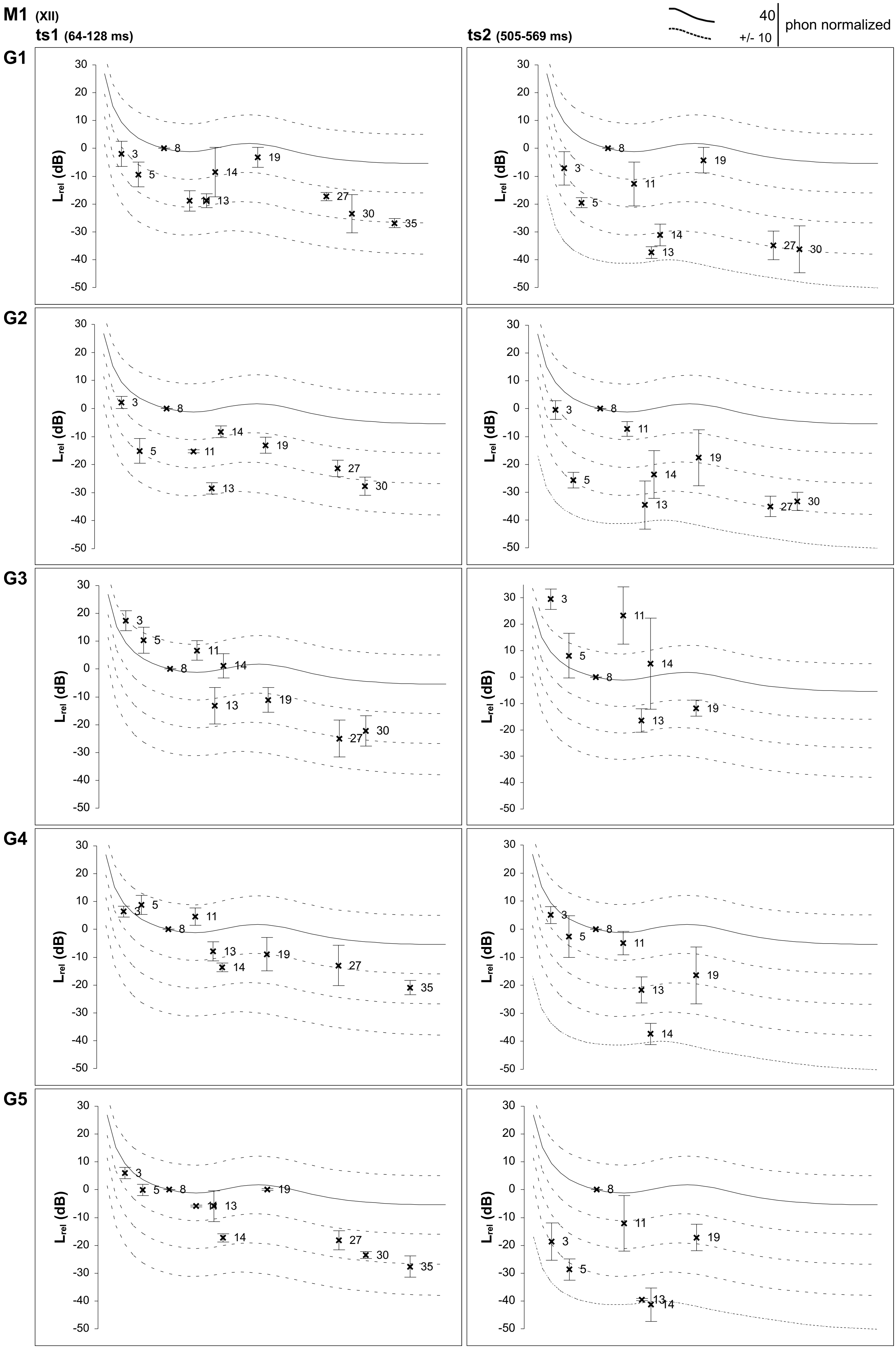
G5




VIII
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_rel (dB)

VIII

M1 (XII)

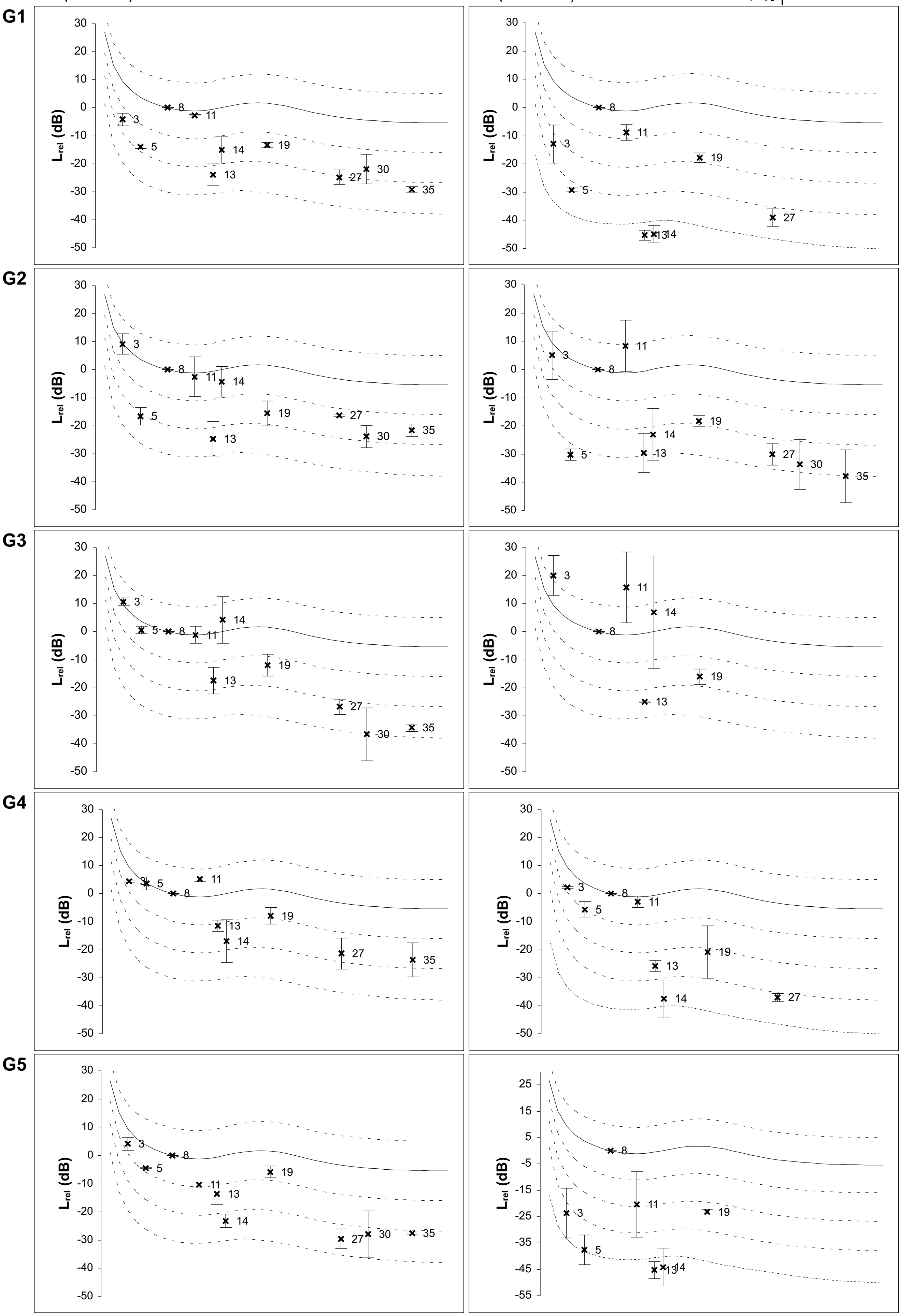

ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
Lrel (dB)

VIII

M2 (Sound hole)

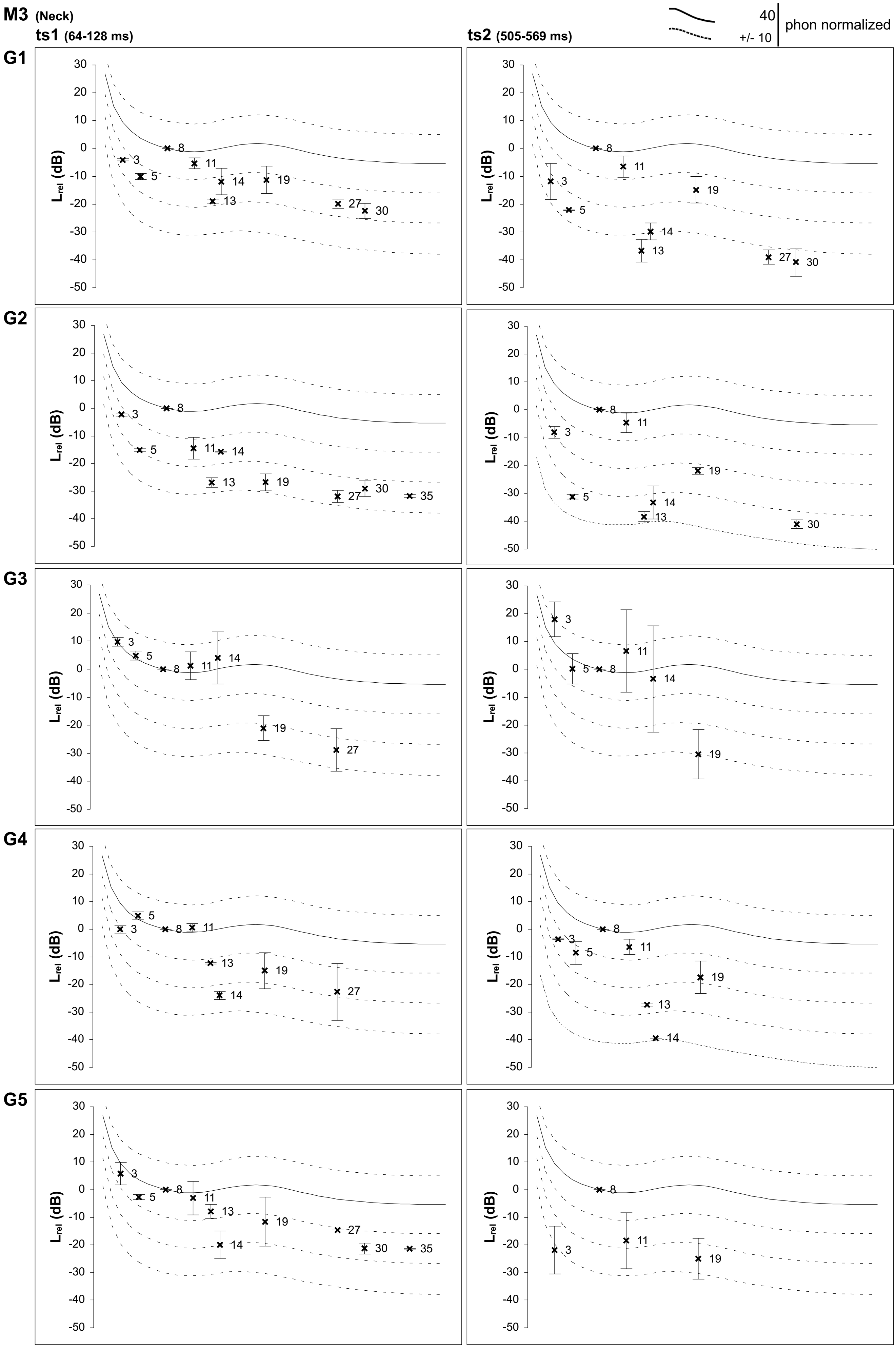
40 / +/- 10 phon normalized

ts1 (64-128 ms) **ts2** (505-569 ms)

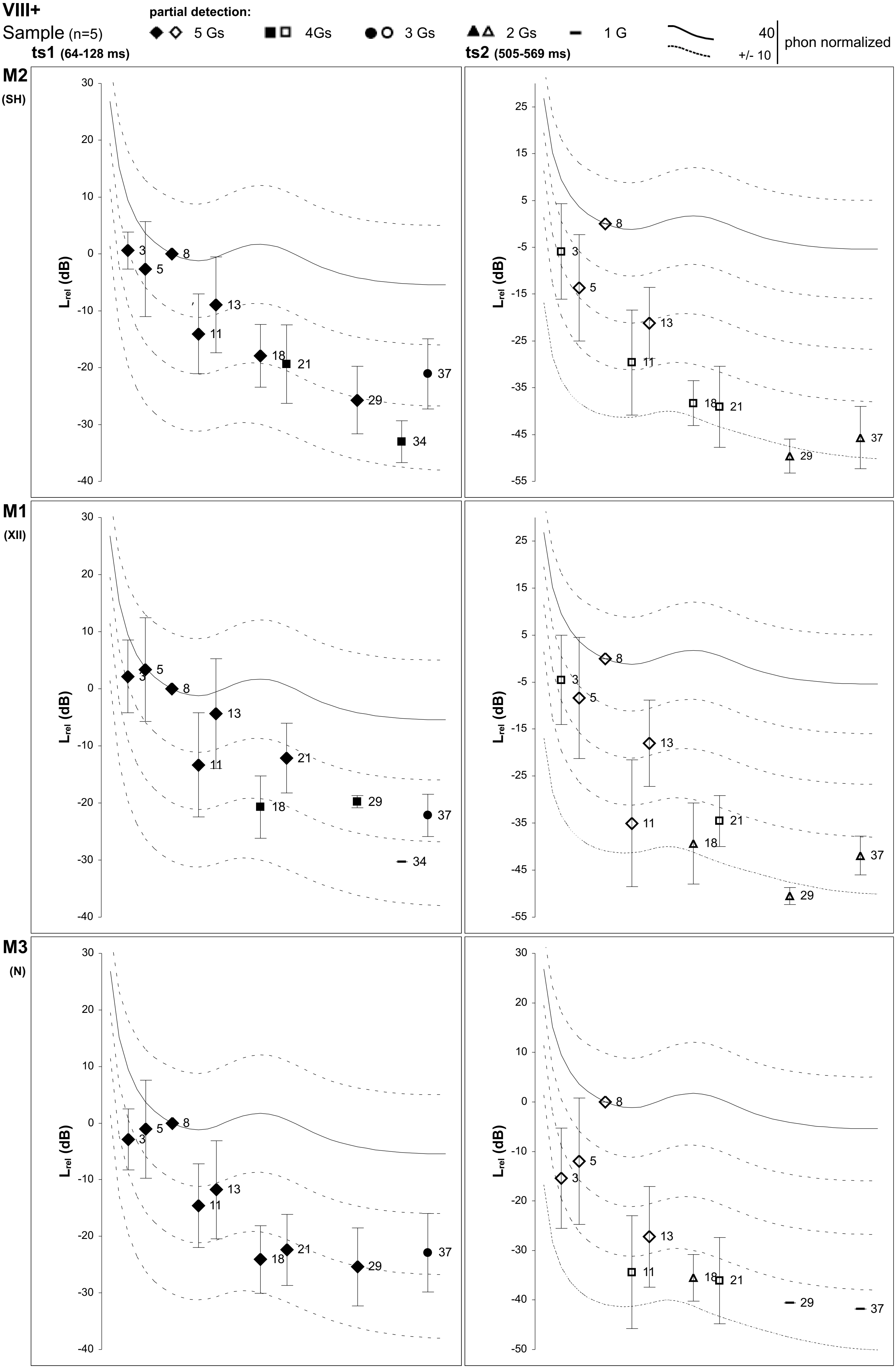


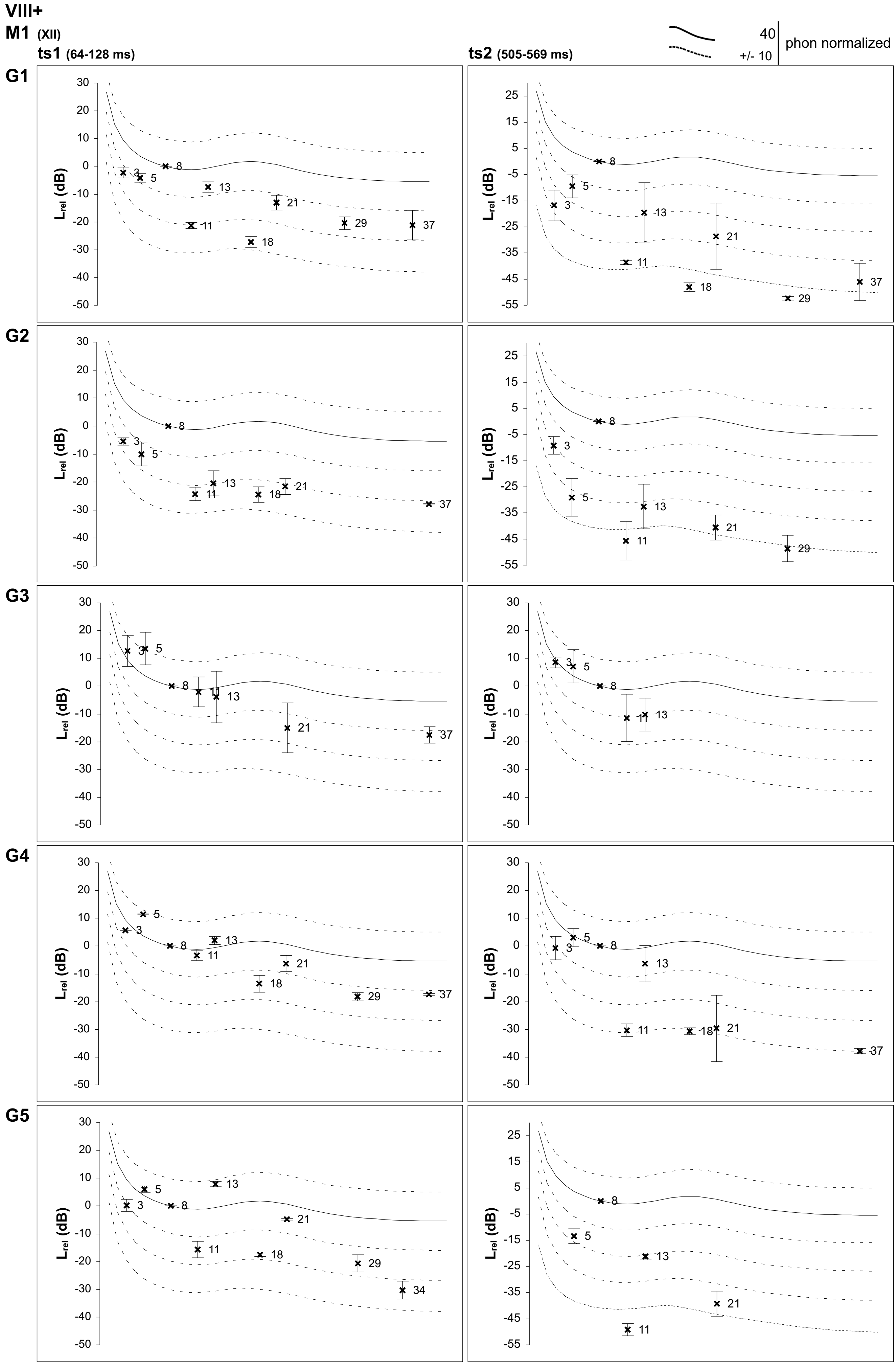
VIII

M3 (Neck)


ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
Lrel (dB)

VIII+
Sample (n=5)

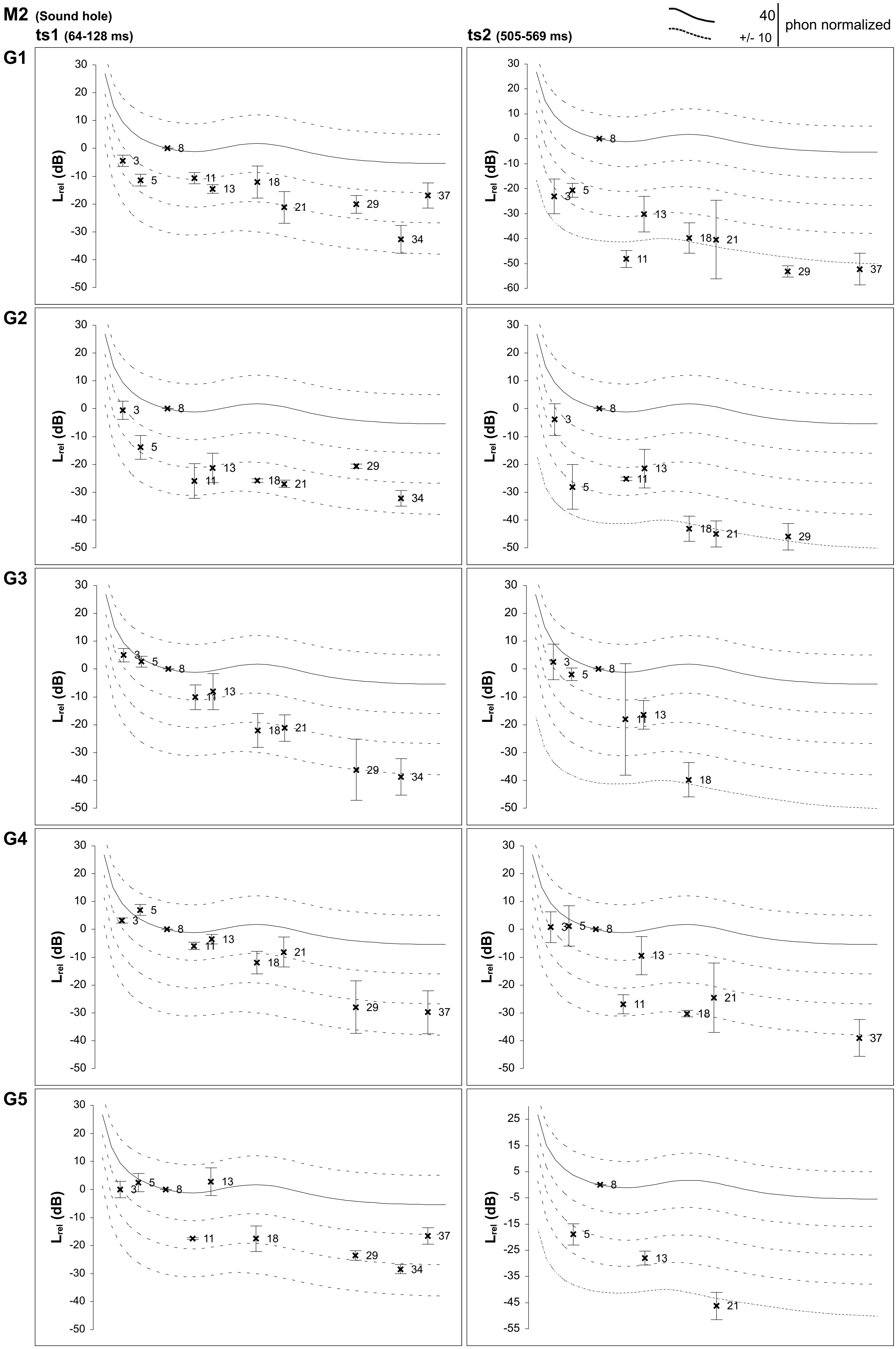



VIII+
M1 (XII)
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
Lrel (dB)

VIII+

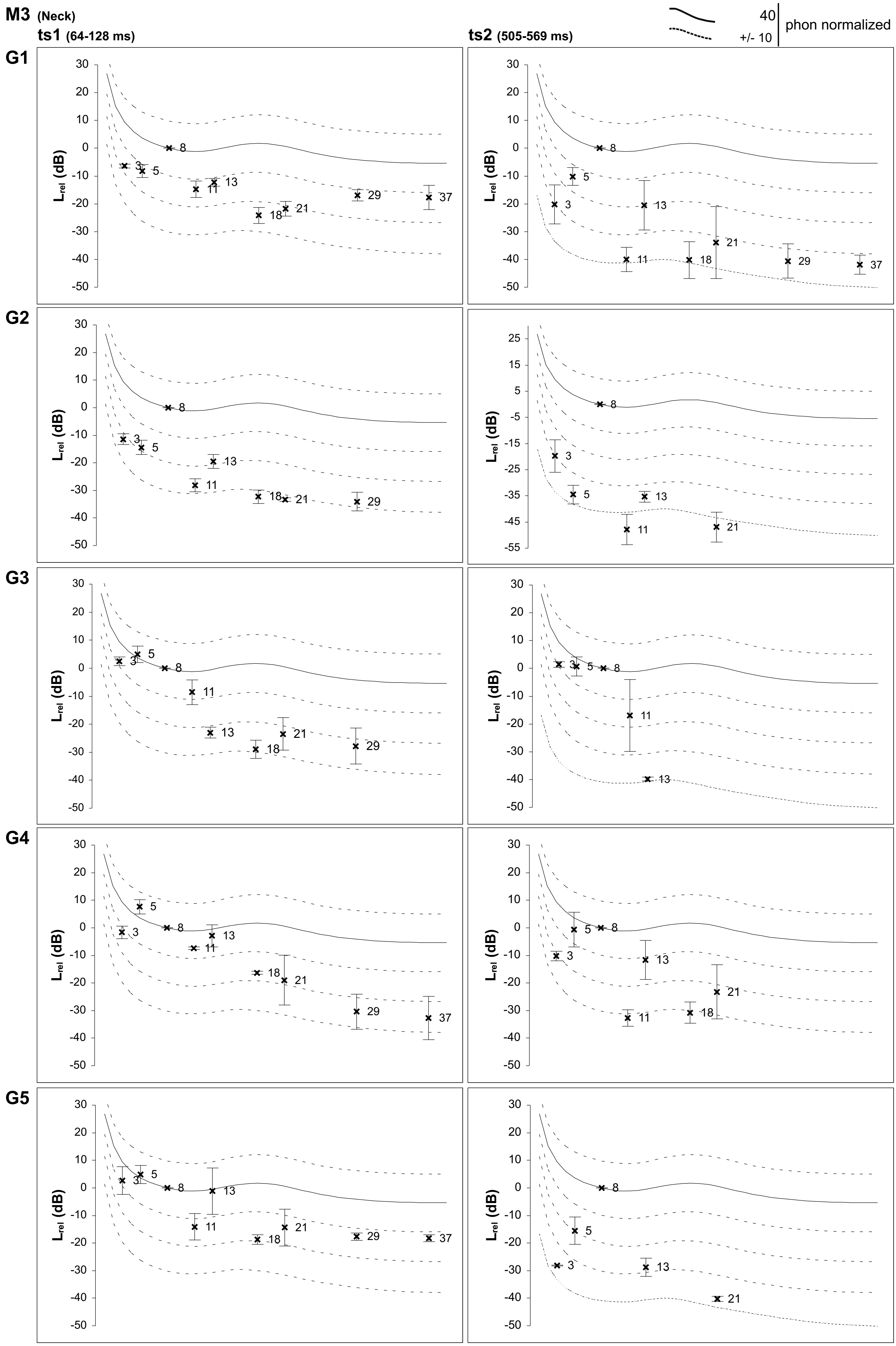
M2 (Sound hole)

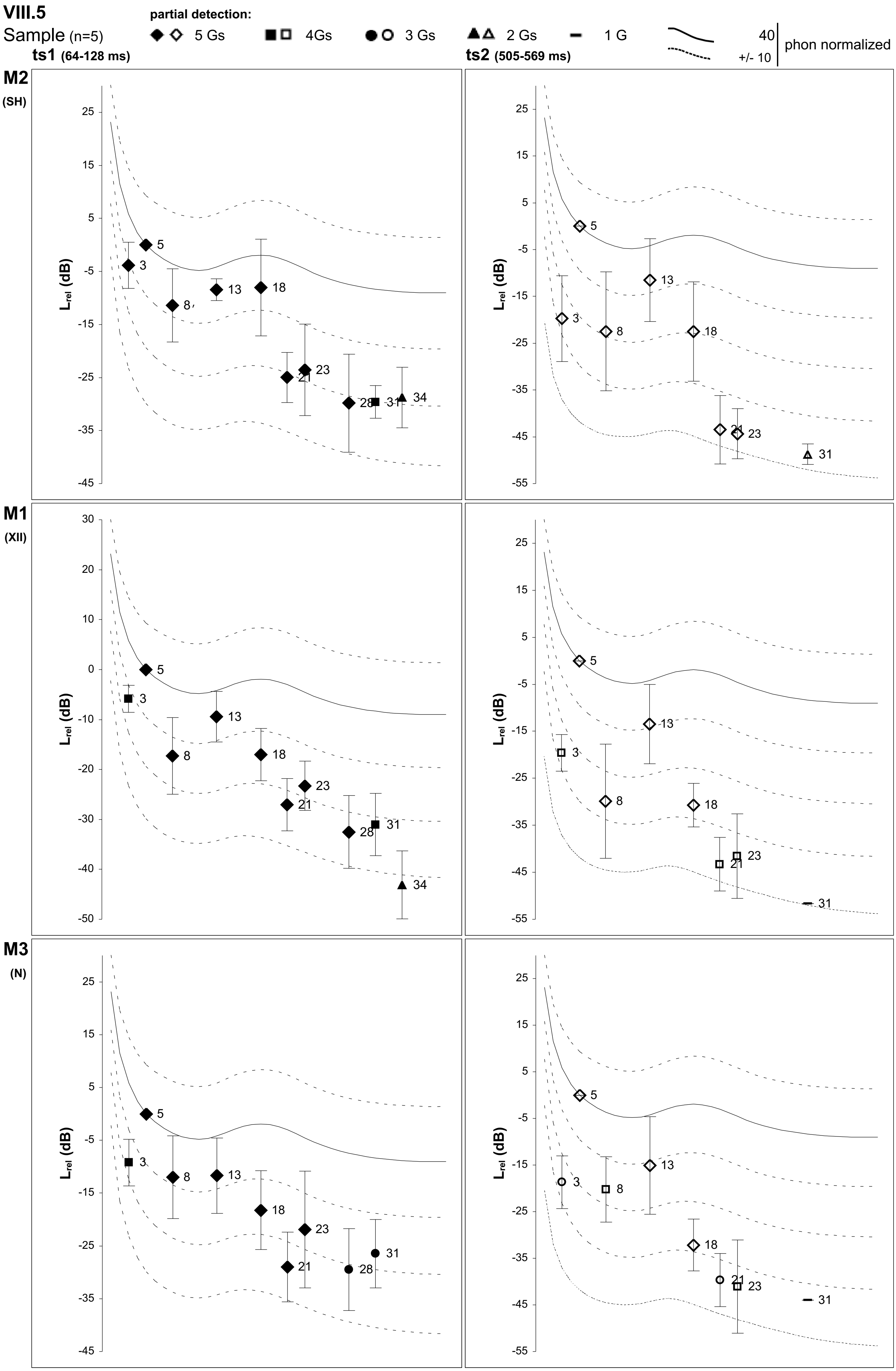
ts1 (64-128 ms) **ts2** (505-569 ms)



VIII+

M3 (Neck)


ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
L_rel (dB)


VIII.5
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_{rel} (dB)
3
5
8
13
18
21
23
28
31
34

VIII.5

M1 (XII)

40 | +/- 10 | phon normalized

ts1 (64-128 ms) **ts2** (505-569 ms)

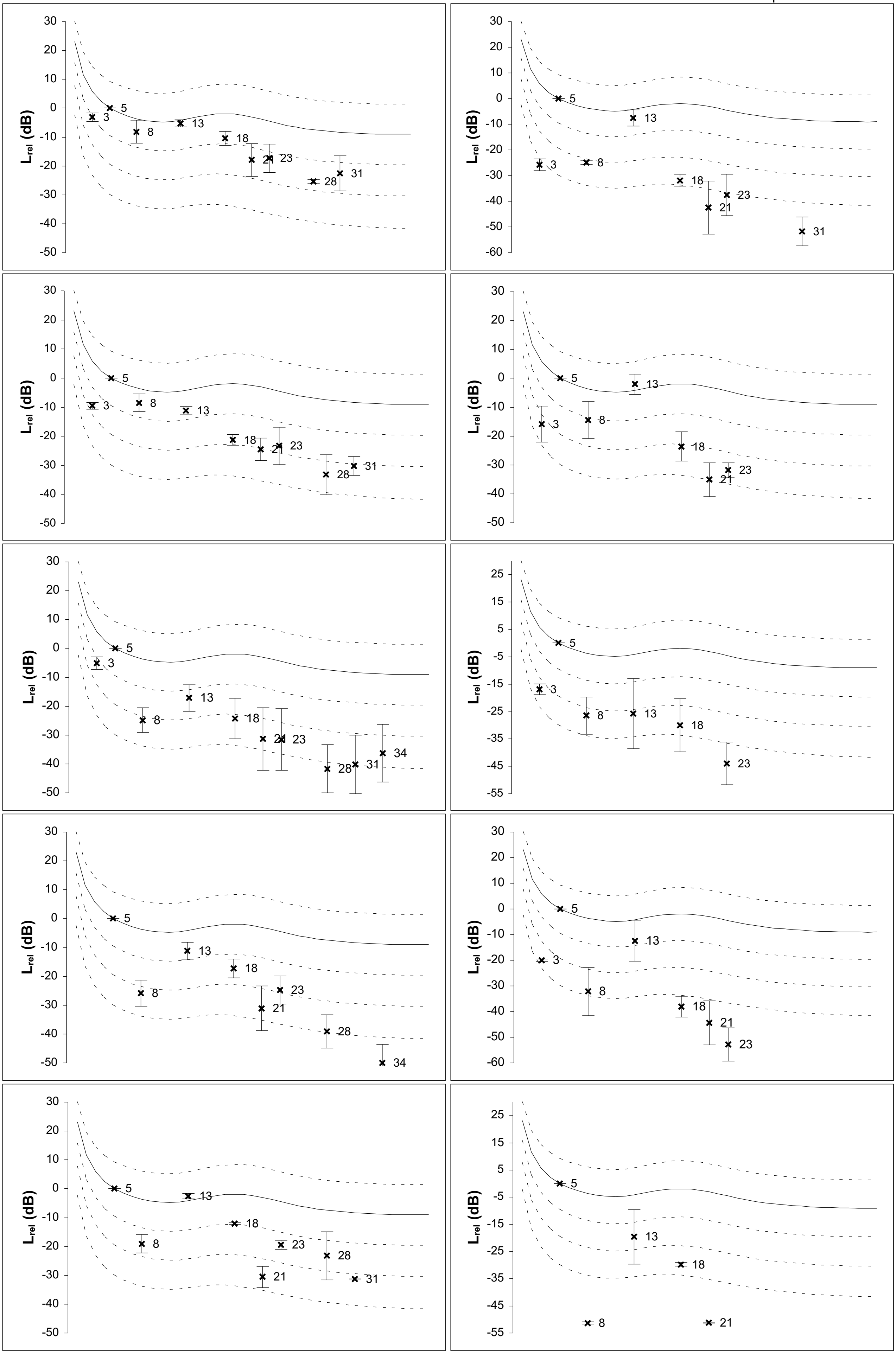
G1

G2

G3

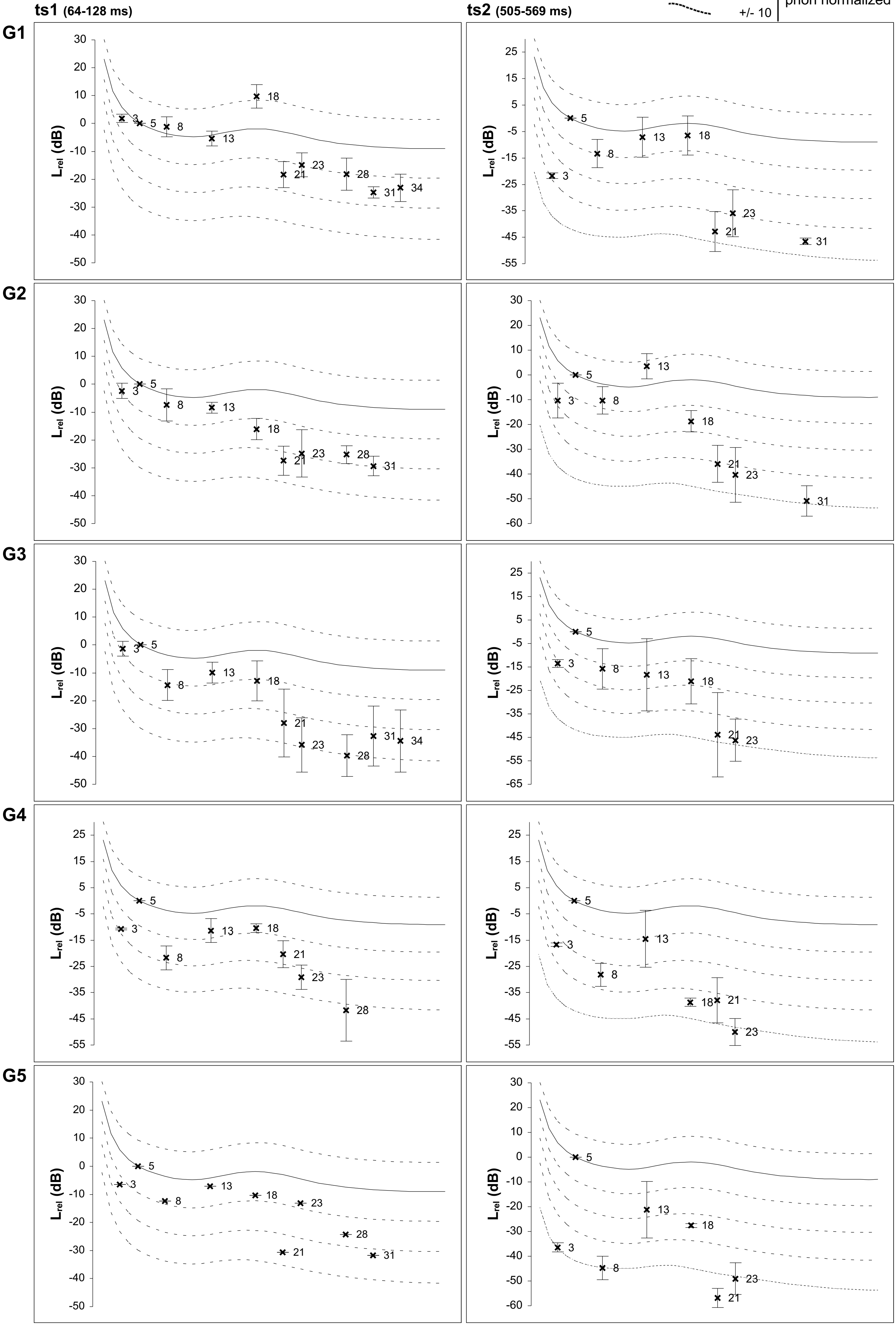
G4

G5



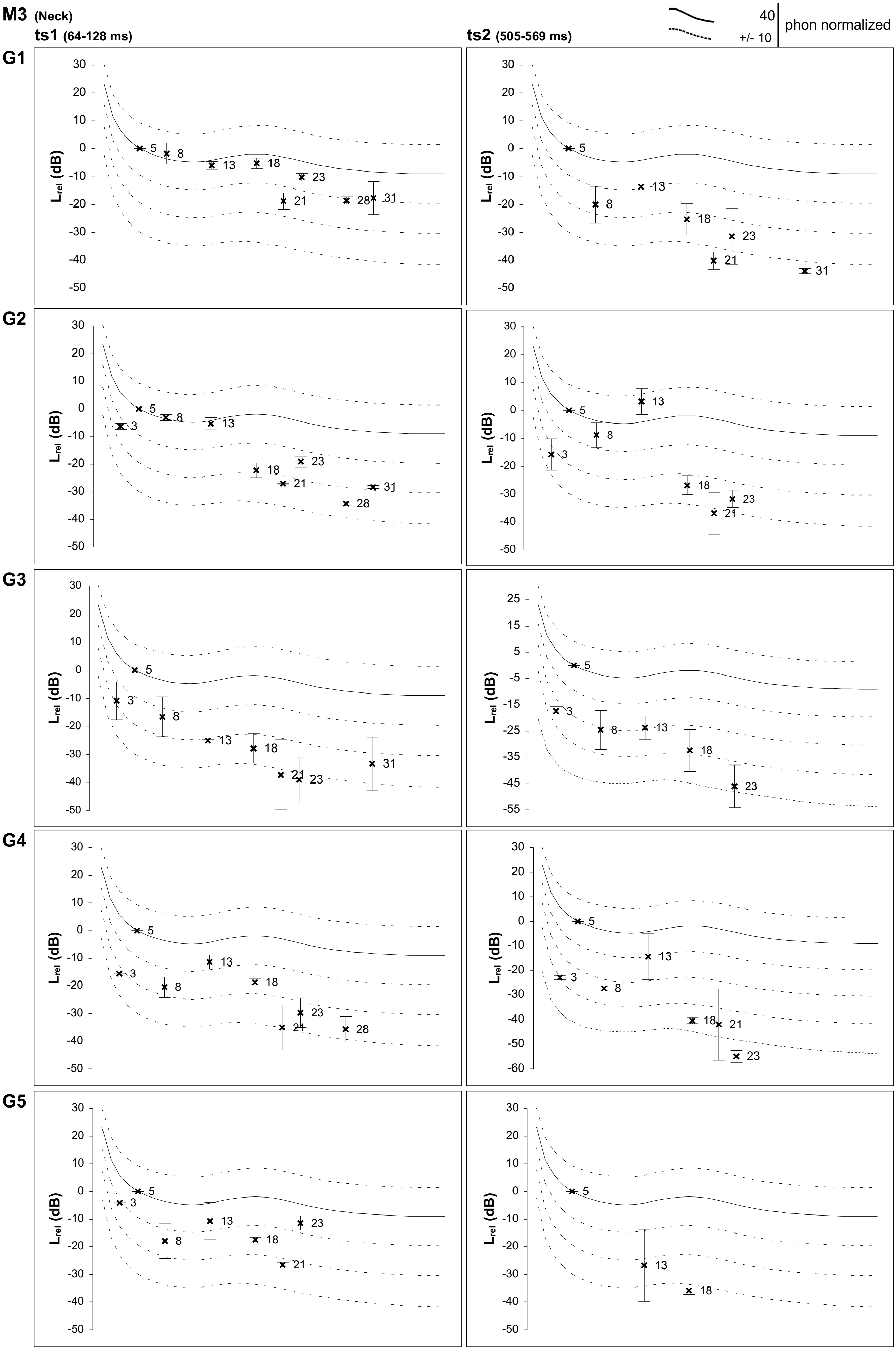
VIII.5

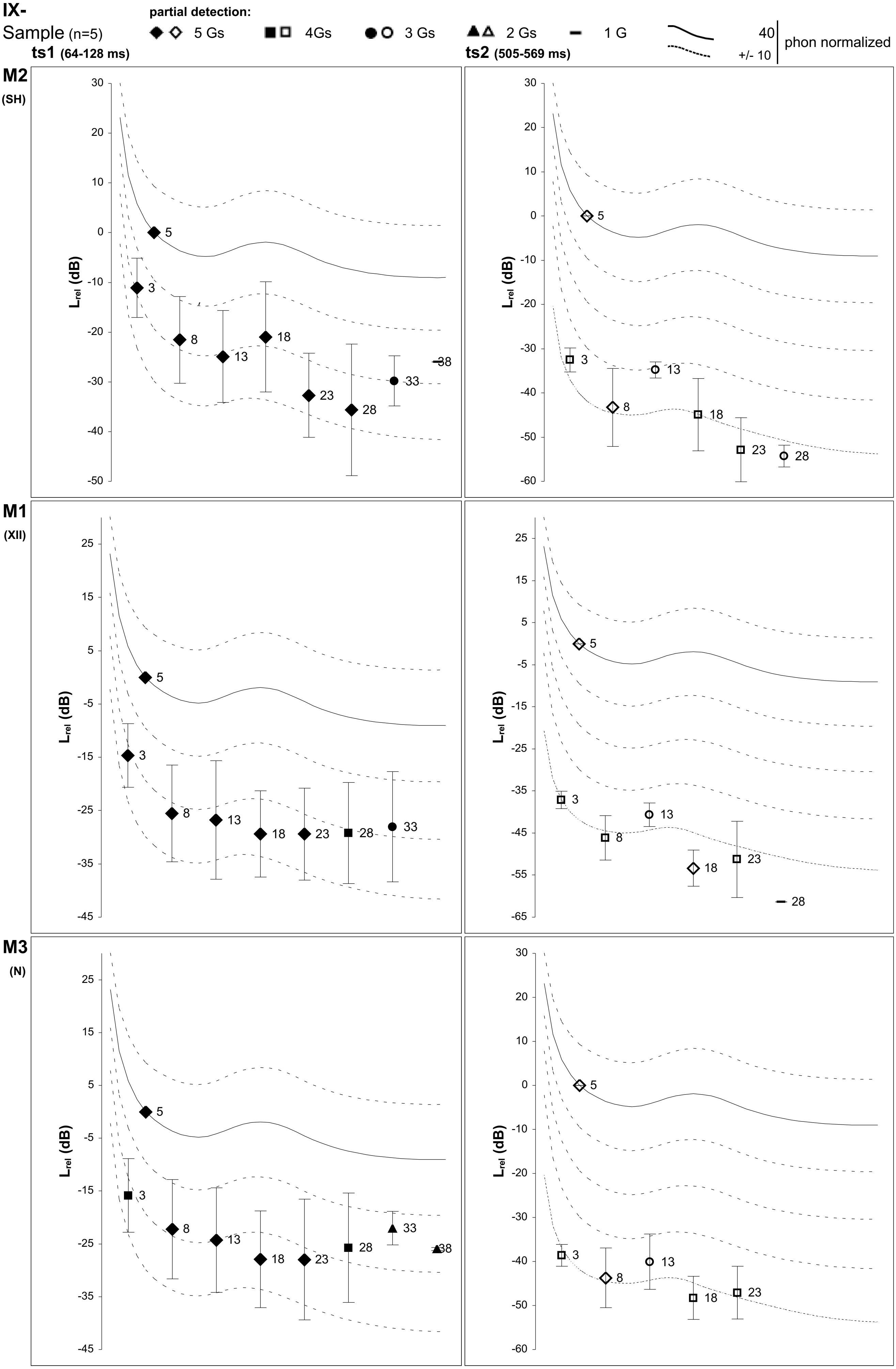
M2 (Sound hole)



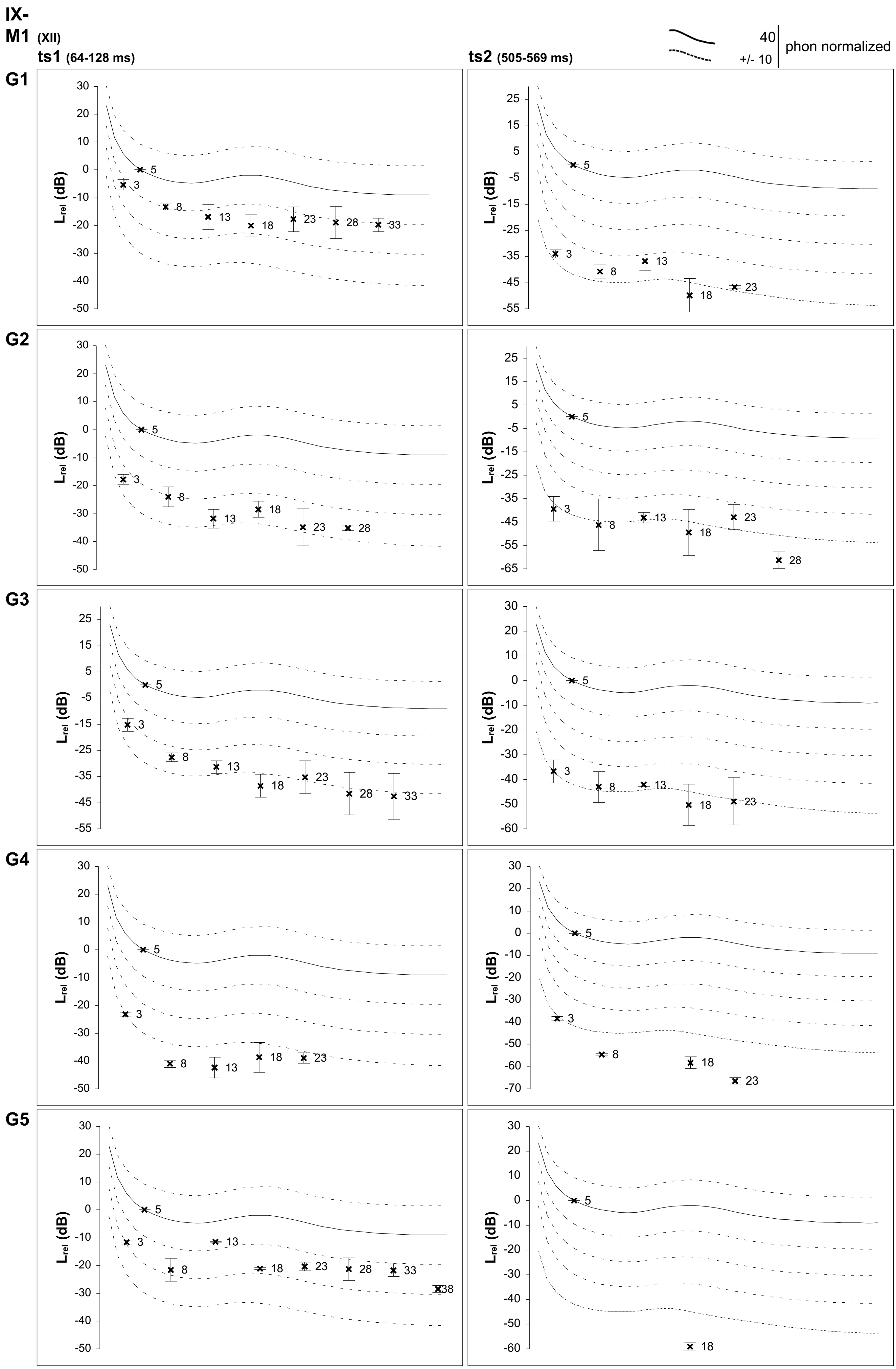
VIII.5

M3 (Neck)





IX-
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_{rel} (dB)


IX-
M1 (XII)
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
Lrel (dB)

IX-

M2 (Sound hole)

ts1 (64-128 ms) **ts2** (505-569 ms)

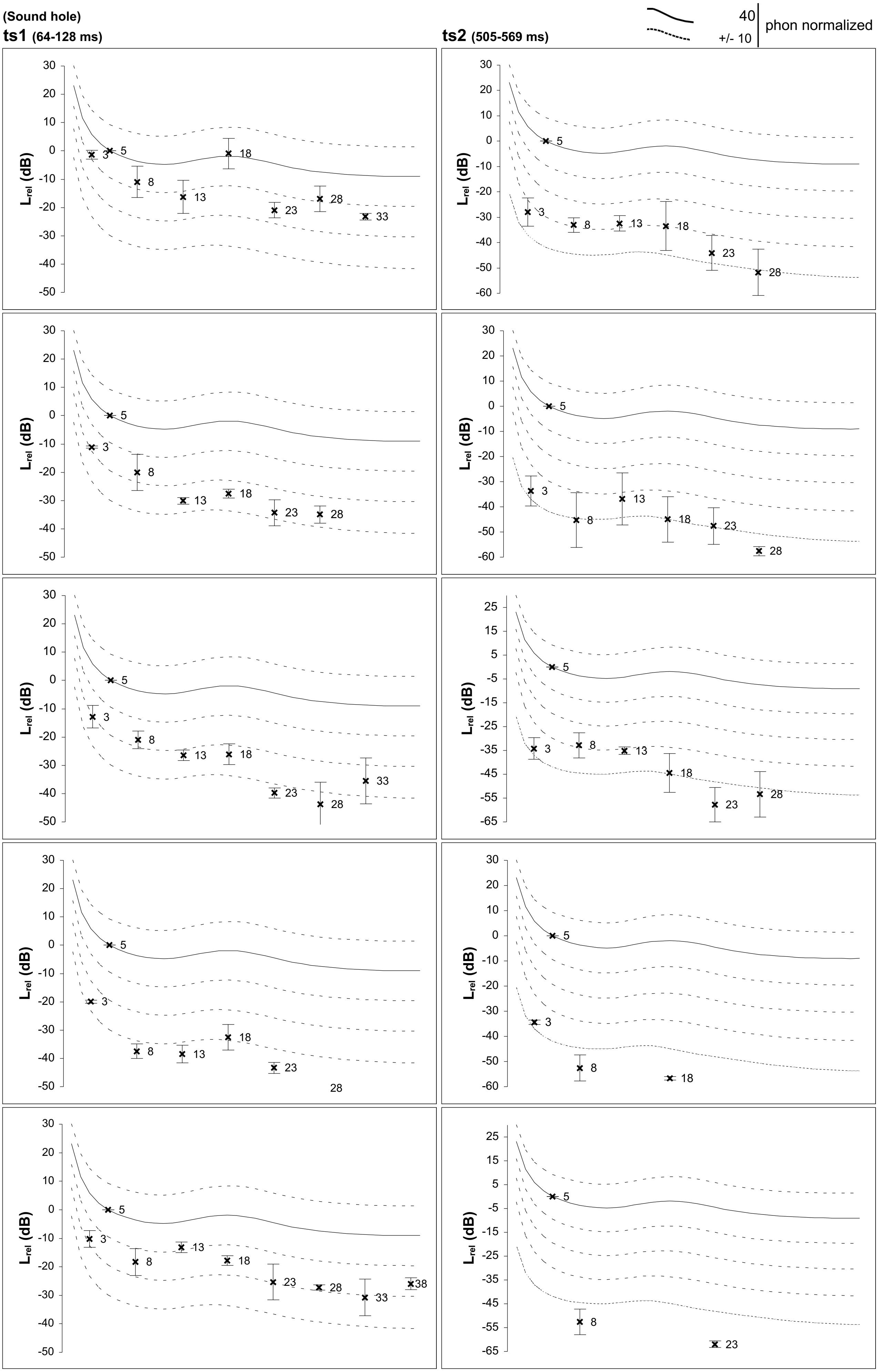
G1

G2

G3

G4

G5



IX-M3 (Neck)

ts1 (64-128 ms) **ts2** (505-569 ms)

40 / +/- 10 phon normalized

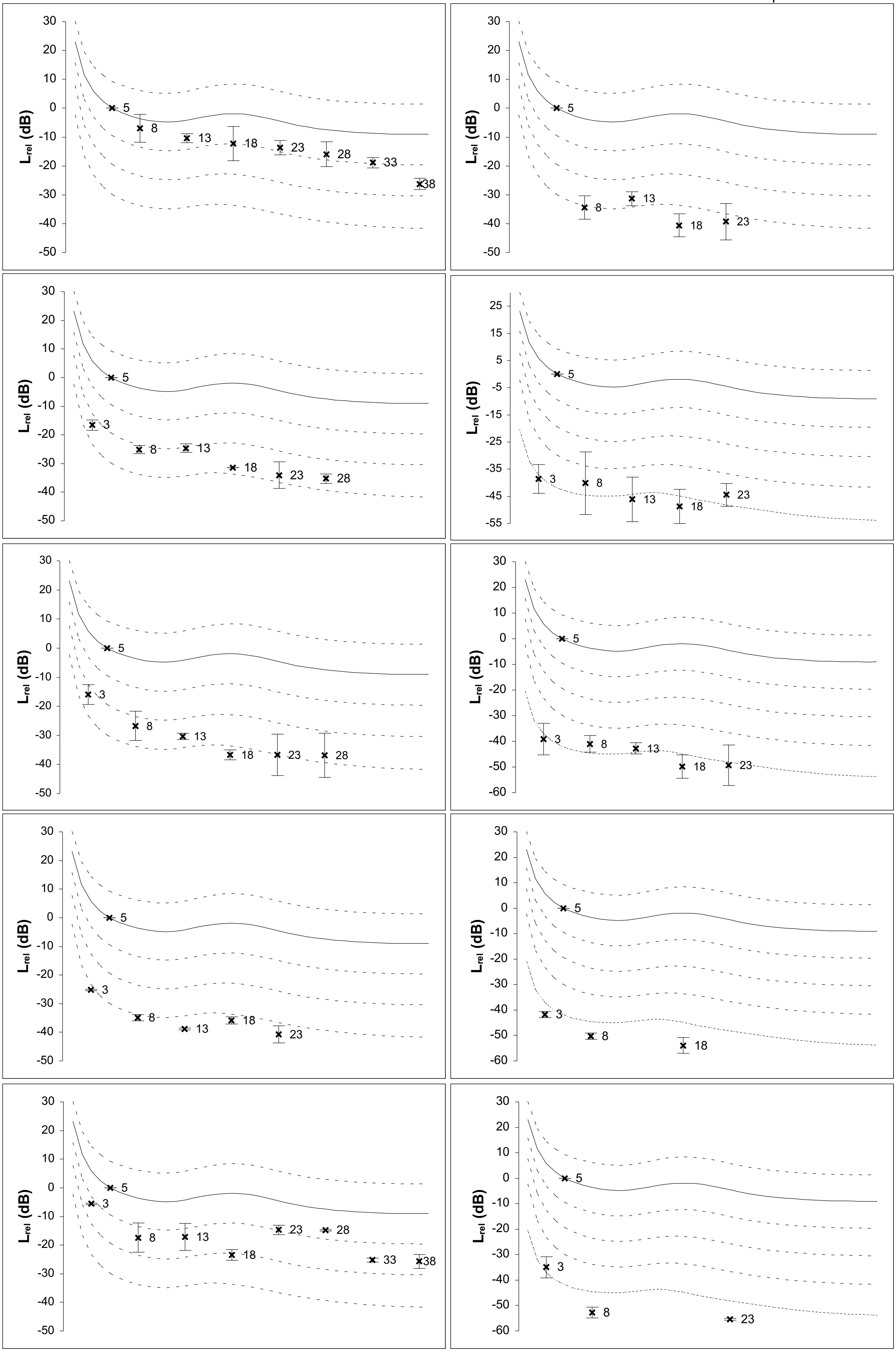
G1

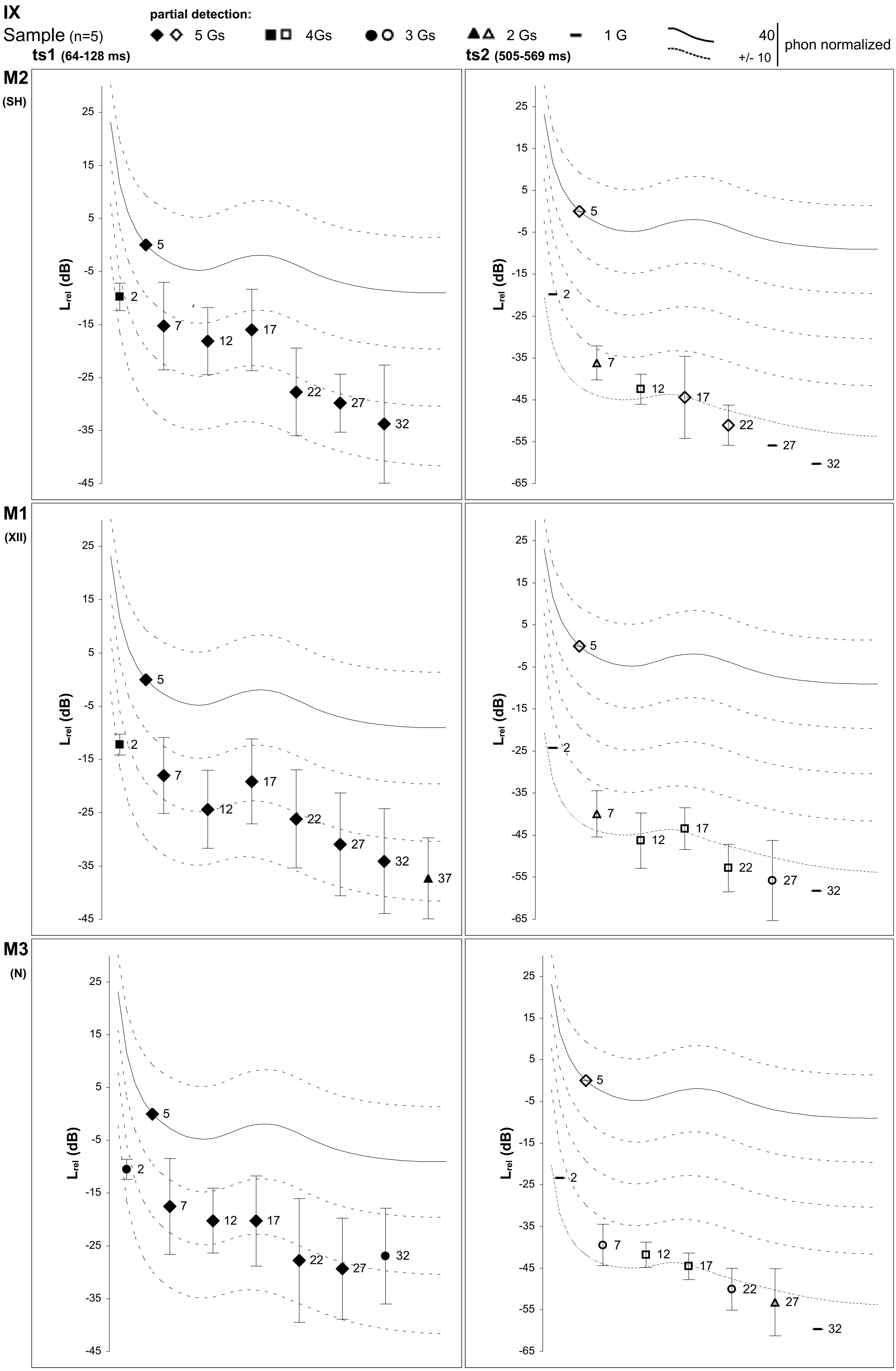
G2

G3

G4

G5

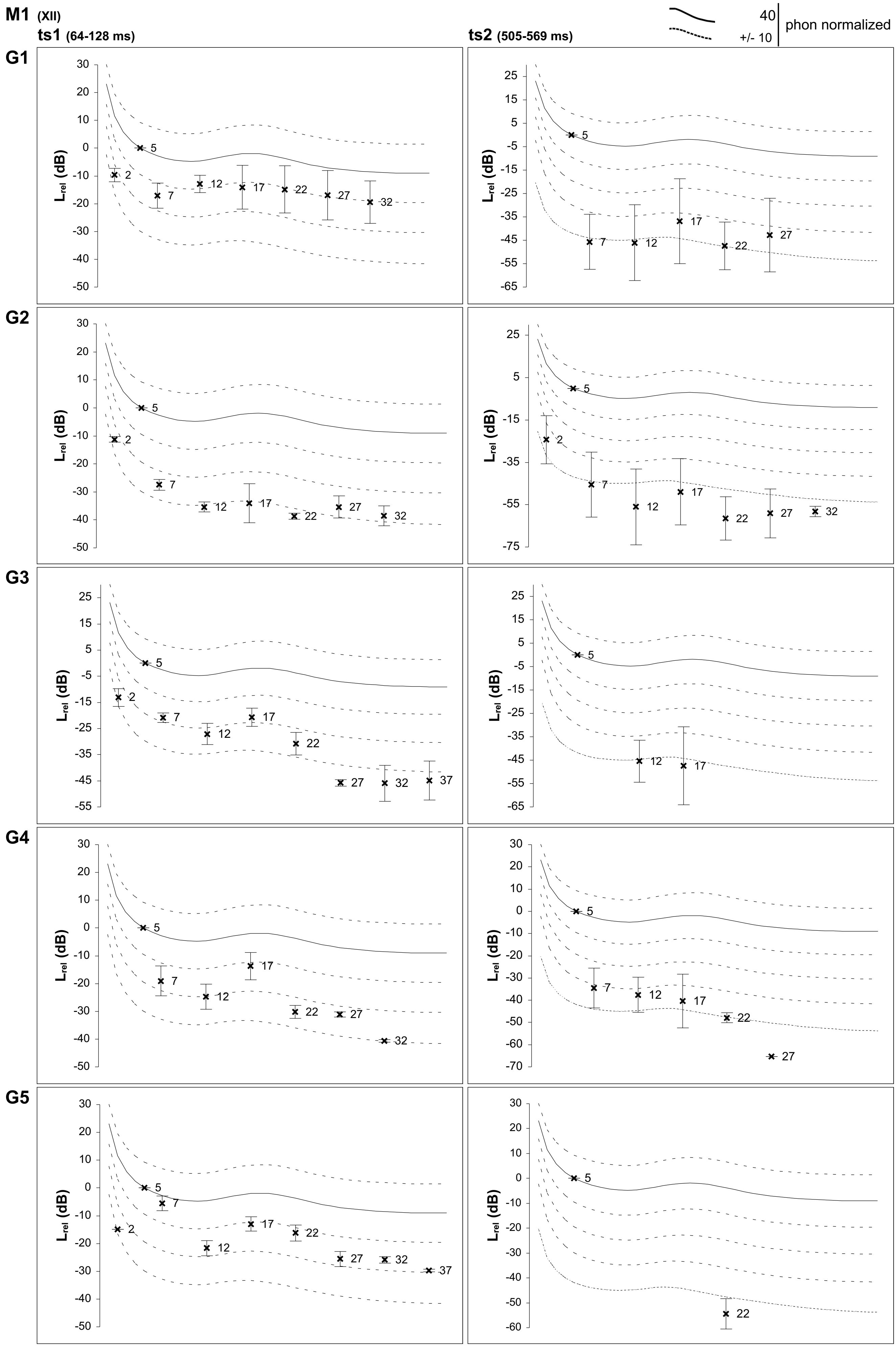




IX
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_rel (dB)

IX

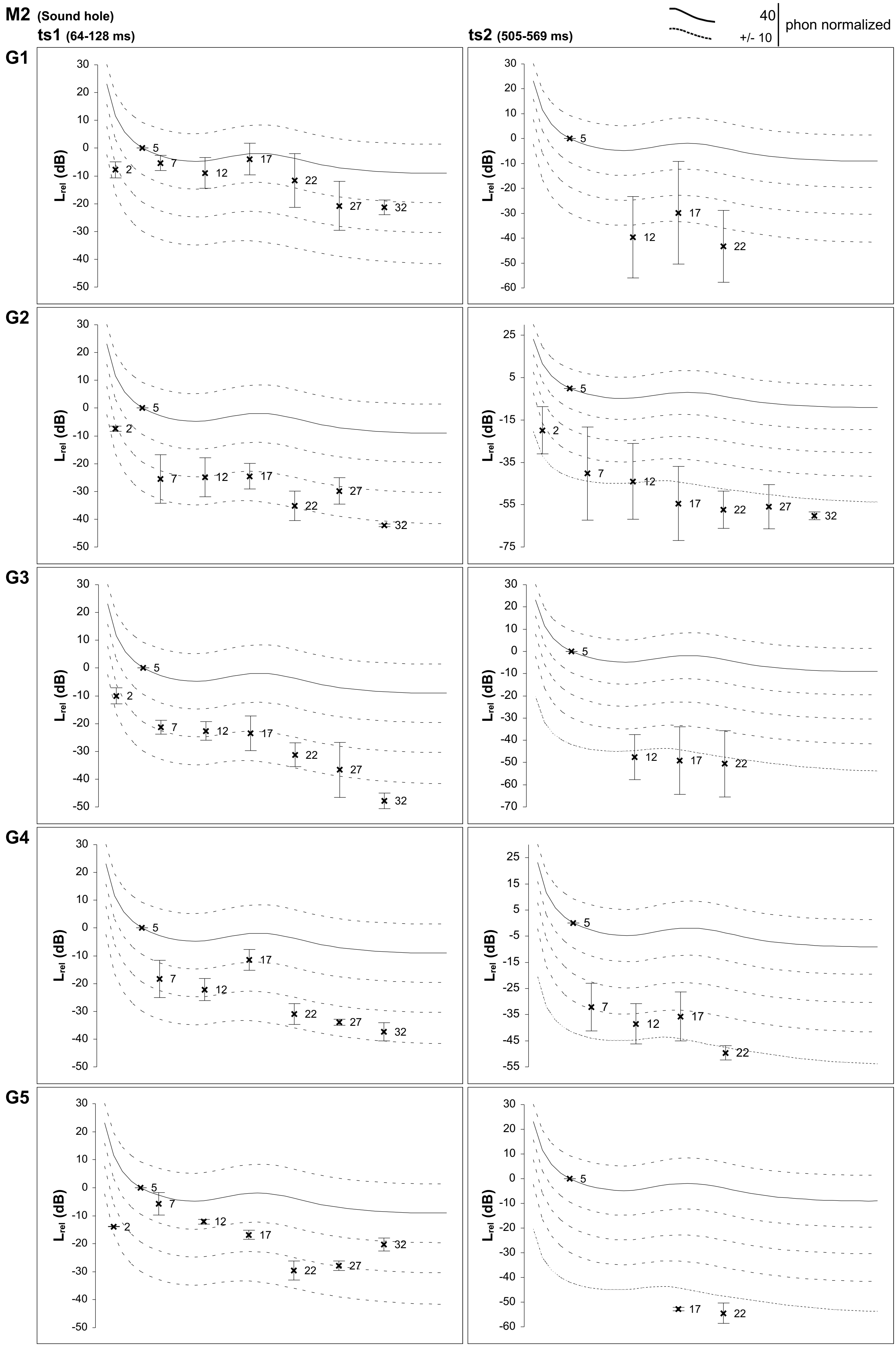
M1 (XII)



40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
G1
G2
G3
G4
G5
L_{rel} (dB)

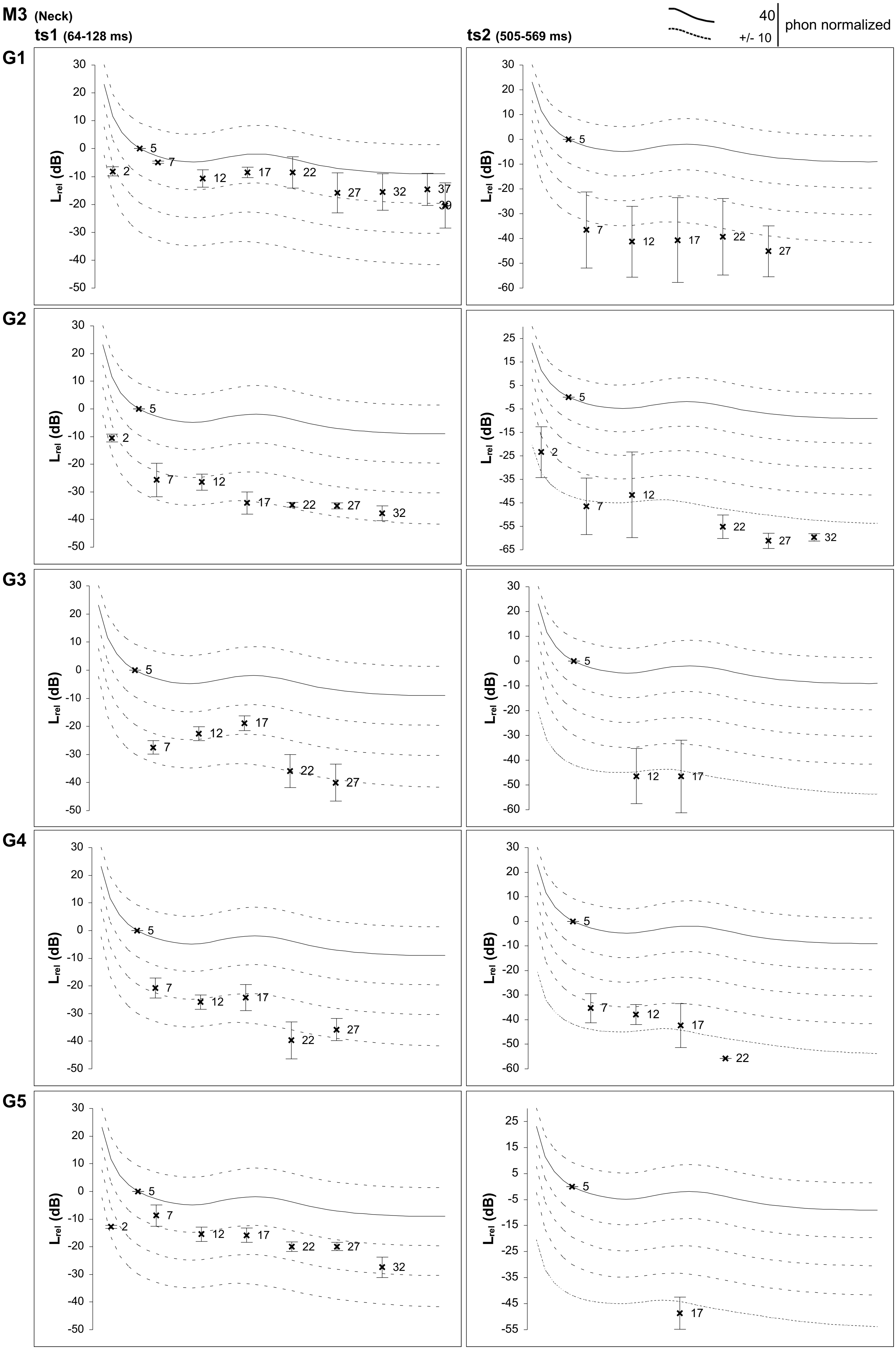
IX

M2 (Sound hole)

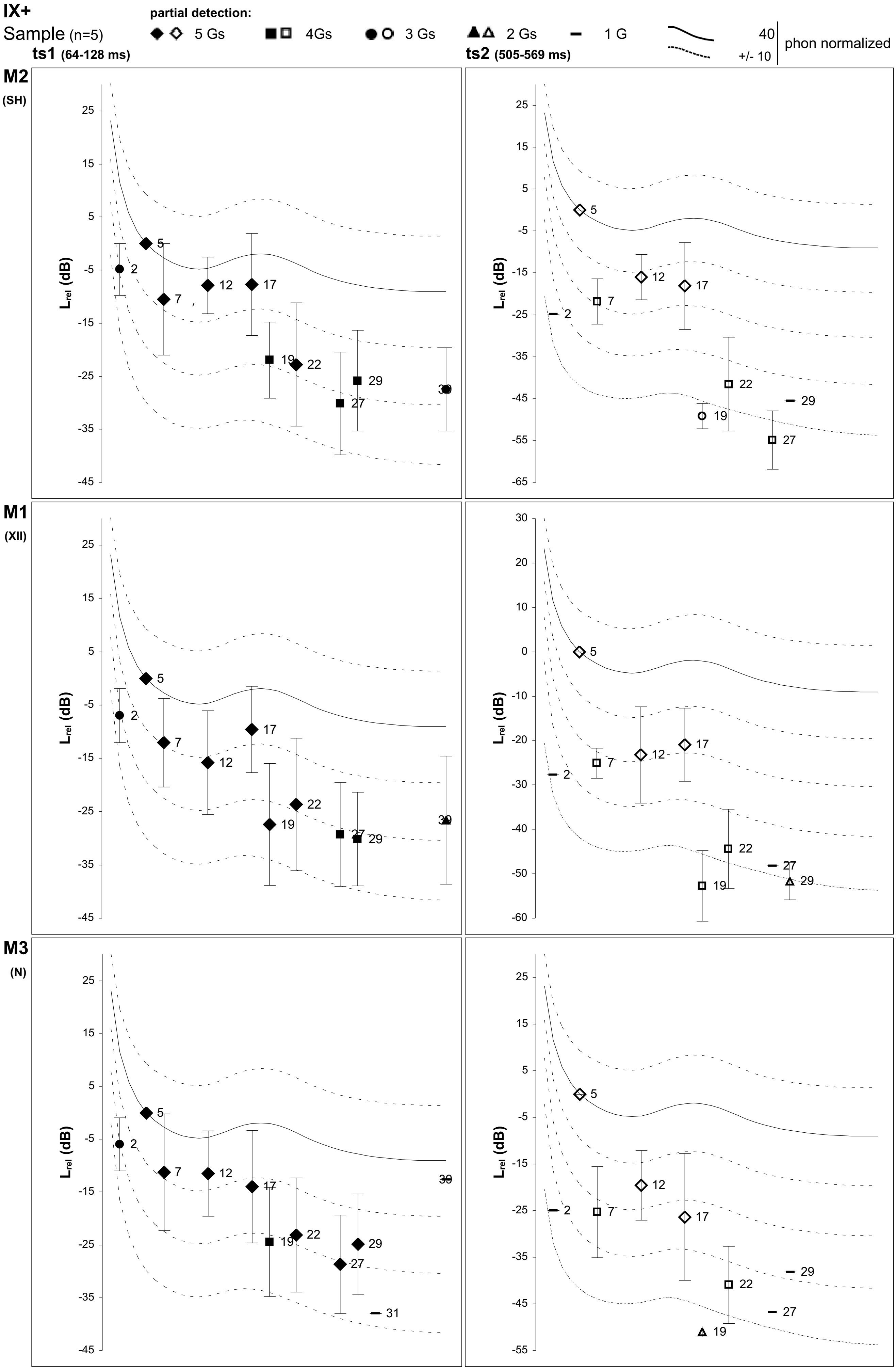


IX

M3 (Neck)



ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
L_{rel} (dB)



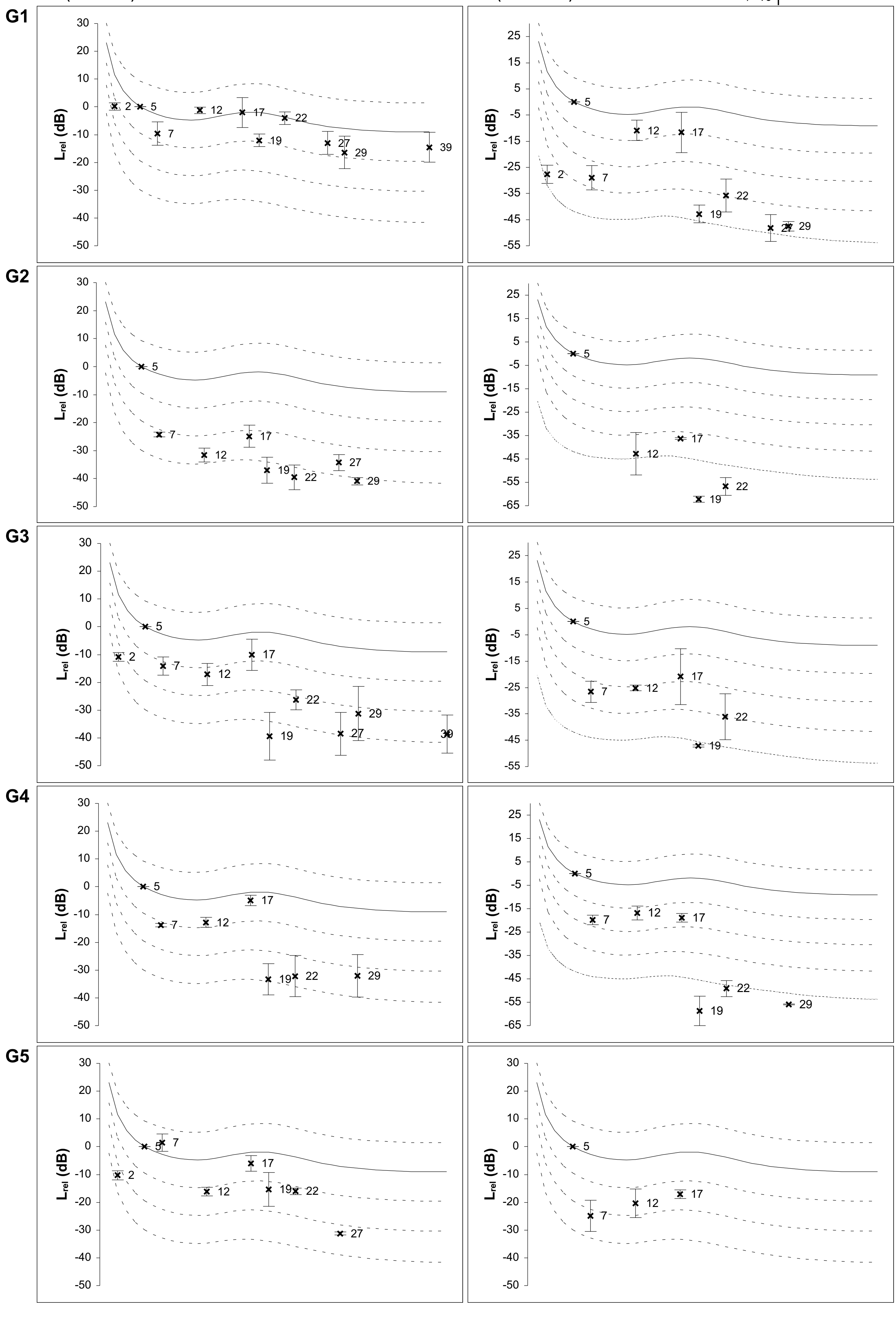
IX+
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
Lrel (dB)

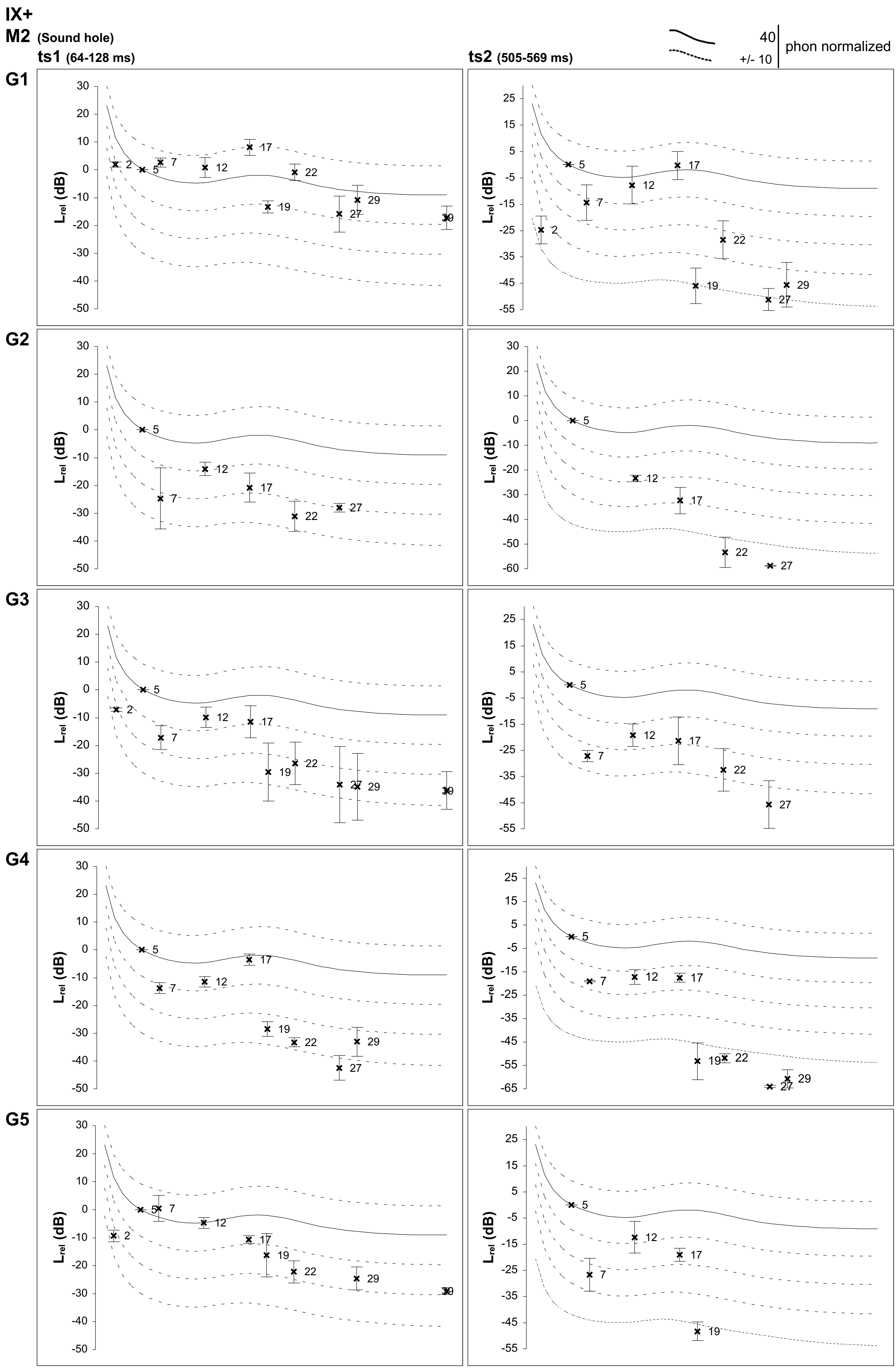
IX+

M1 (XII)

40 / +/- 10 — phon normalized

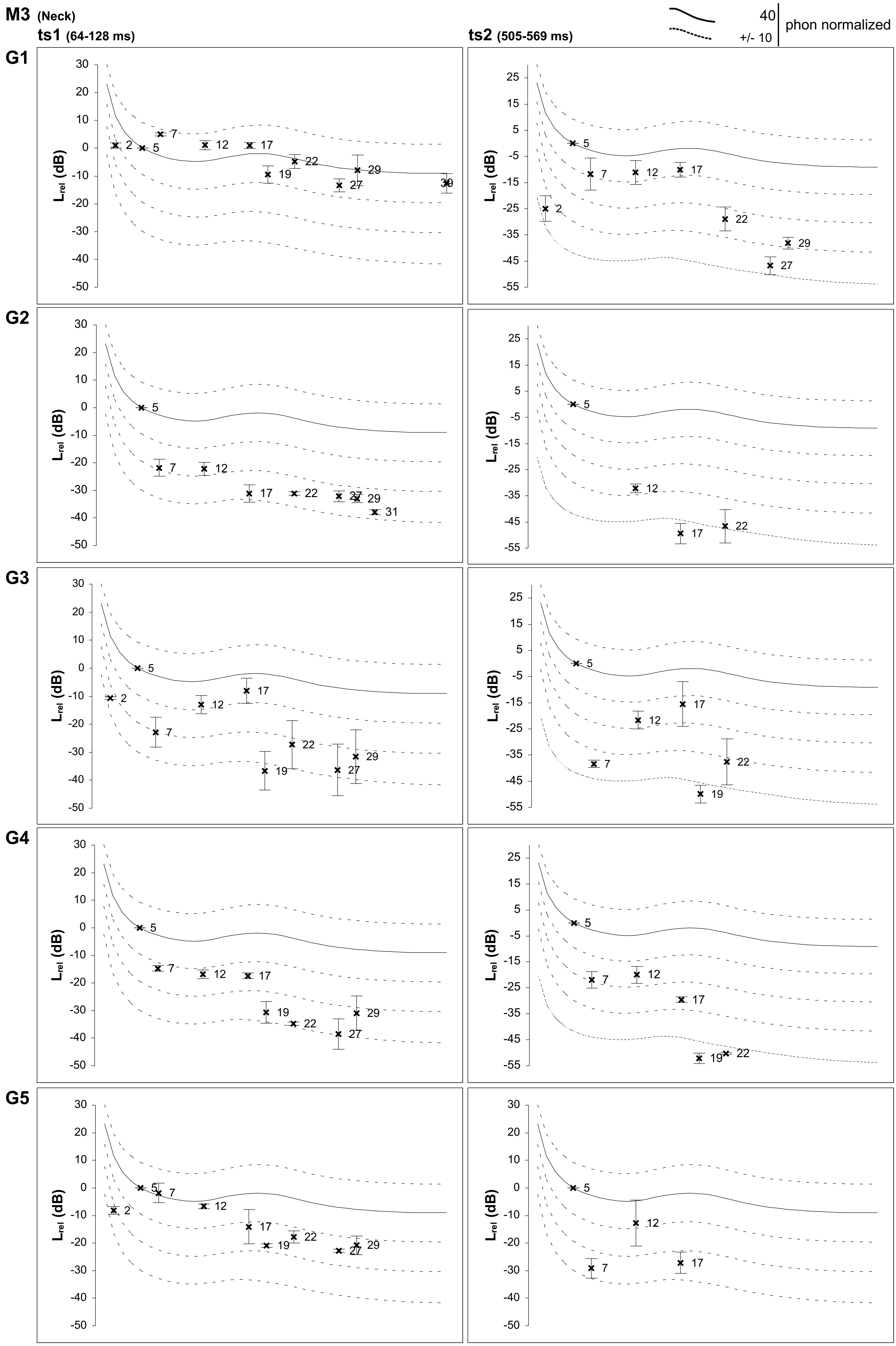
ts1 (64-128 ms) **ts2** (505-569 ms)



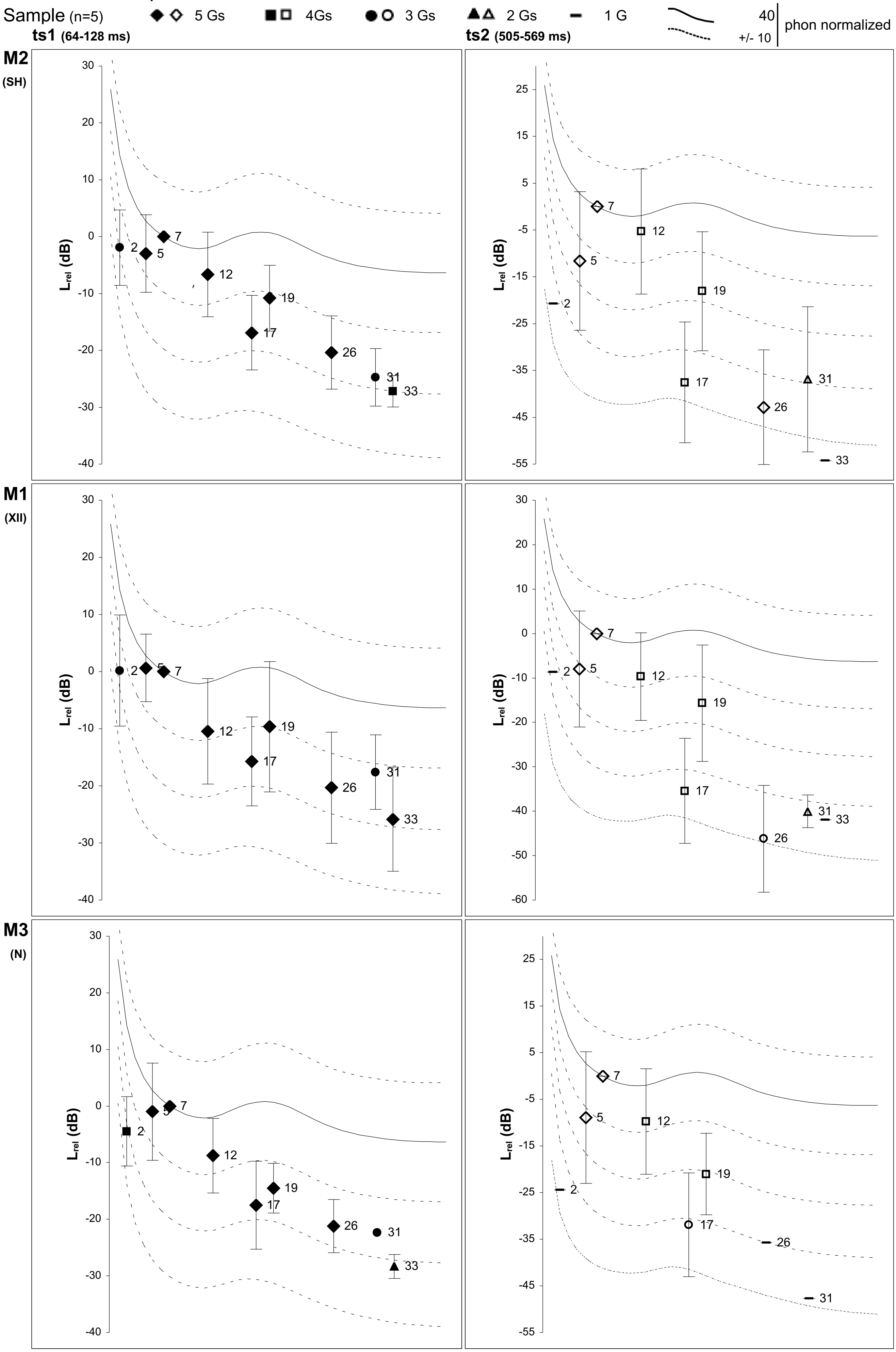

IX+
M2 (Sound hole)
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
Lrel (dB)

IX+

M3 (Neck)

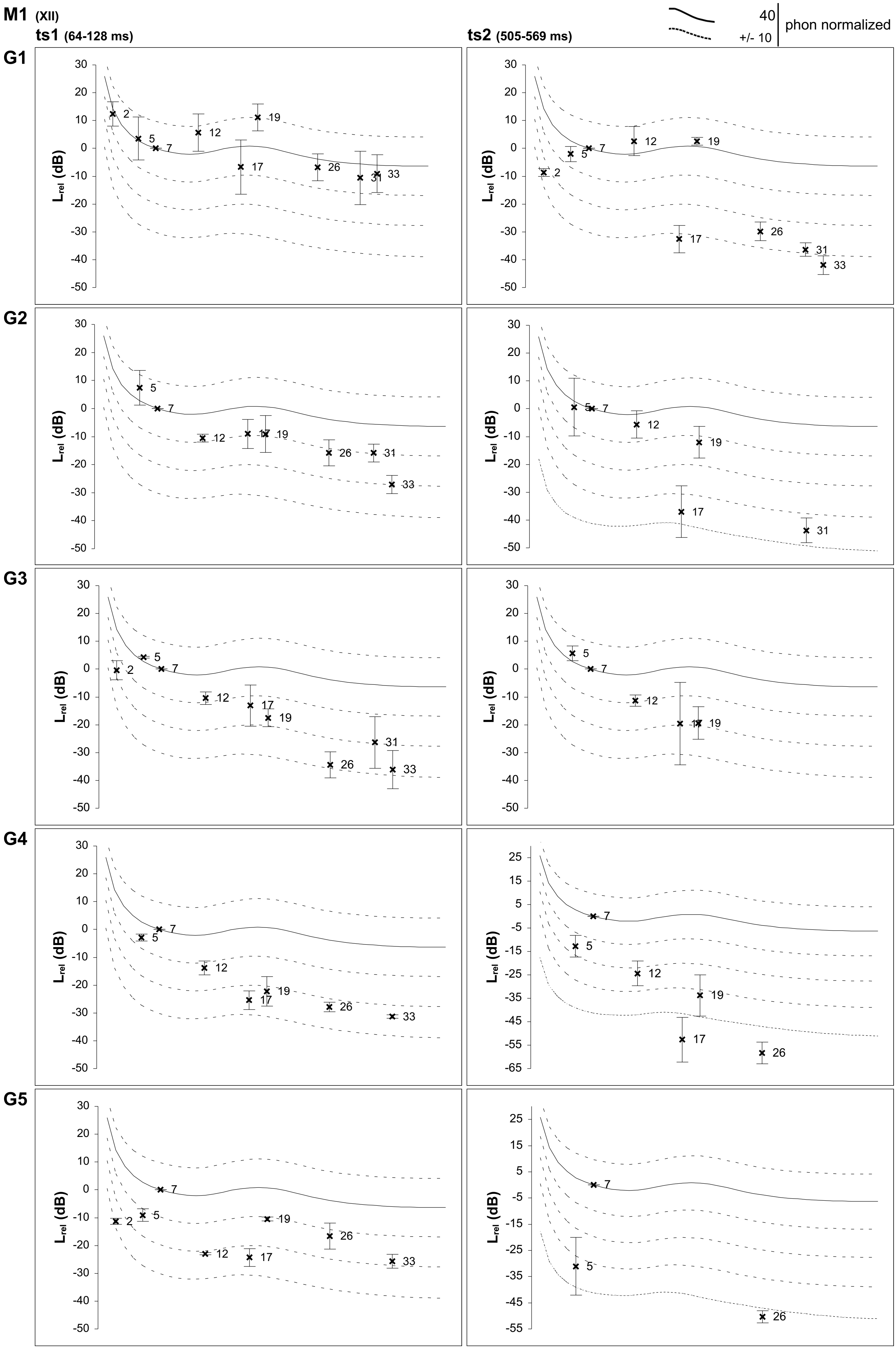

ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
L_{rel} (dB)

IX.5


Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_rel (dB)

IX.5

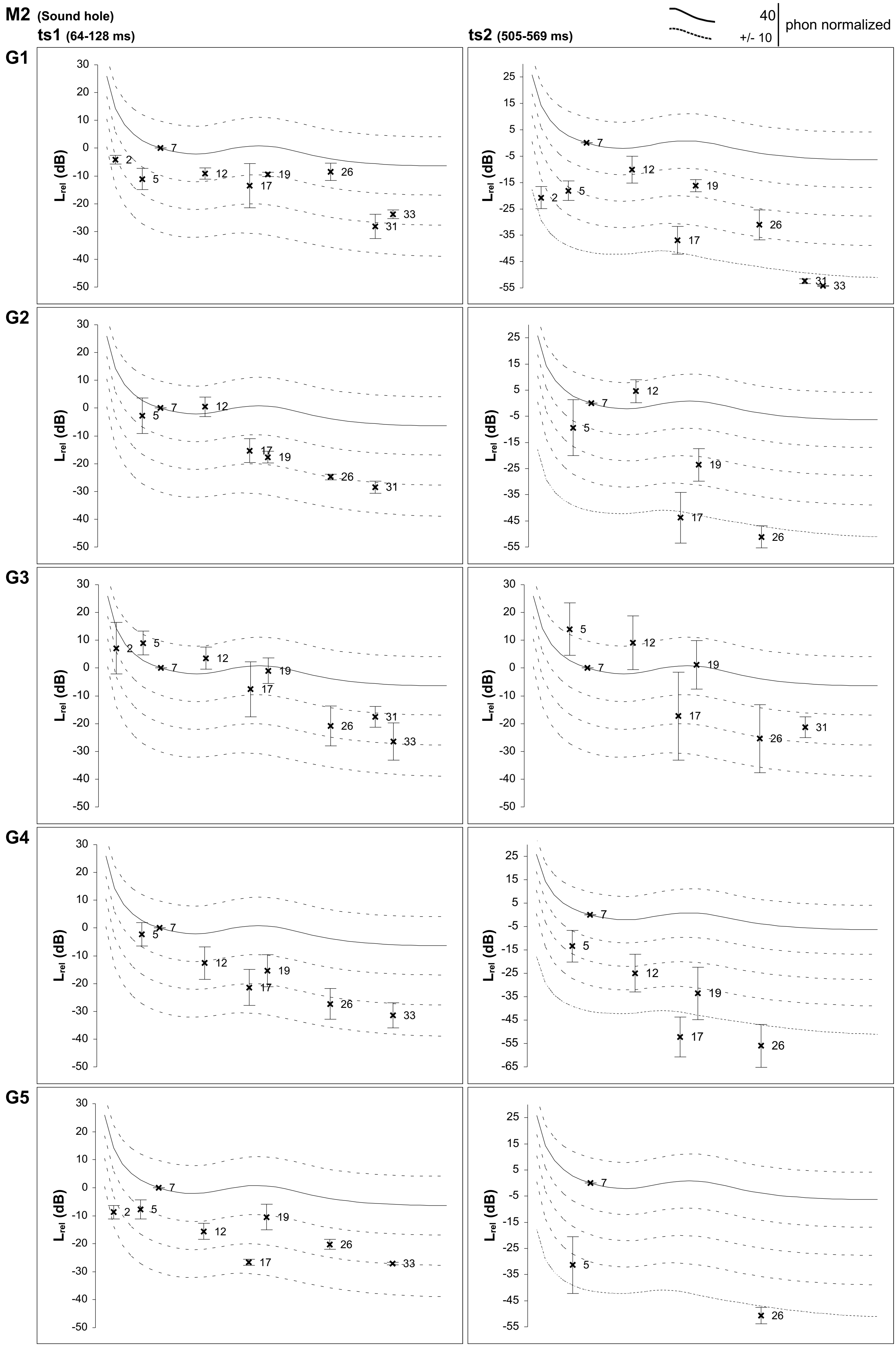
M1 (XII)



40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
G1
G2
G3
G4
G5
Lrel (dB)

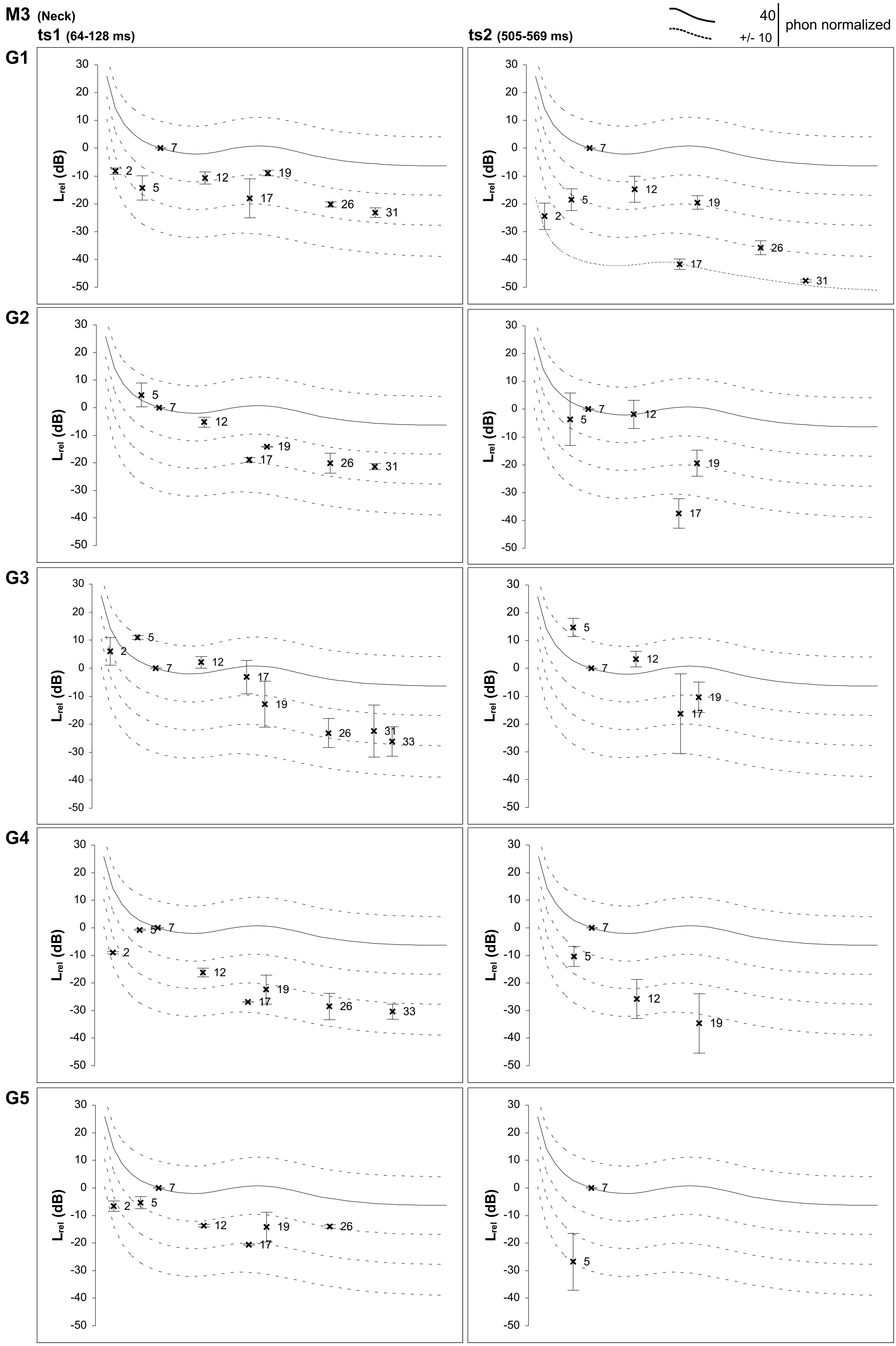
IX.5

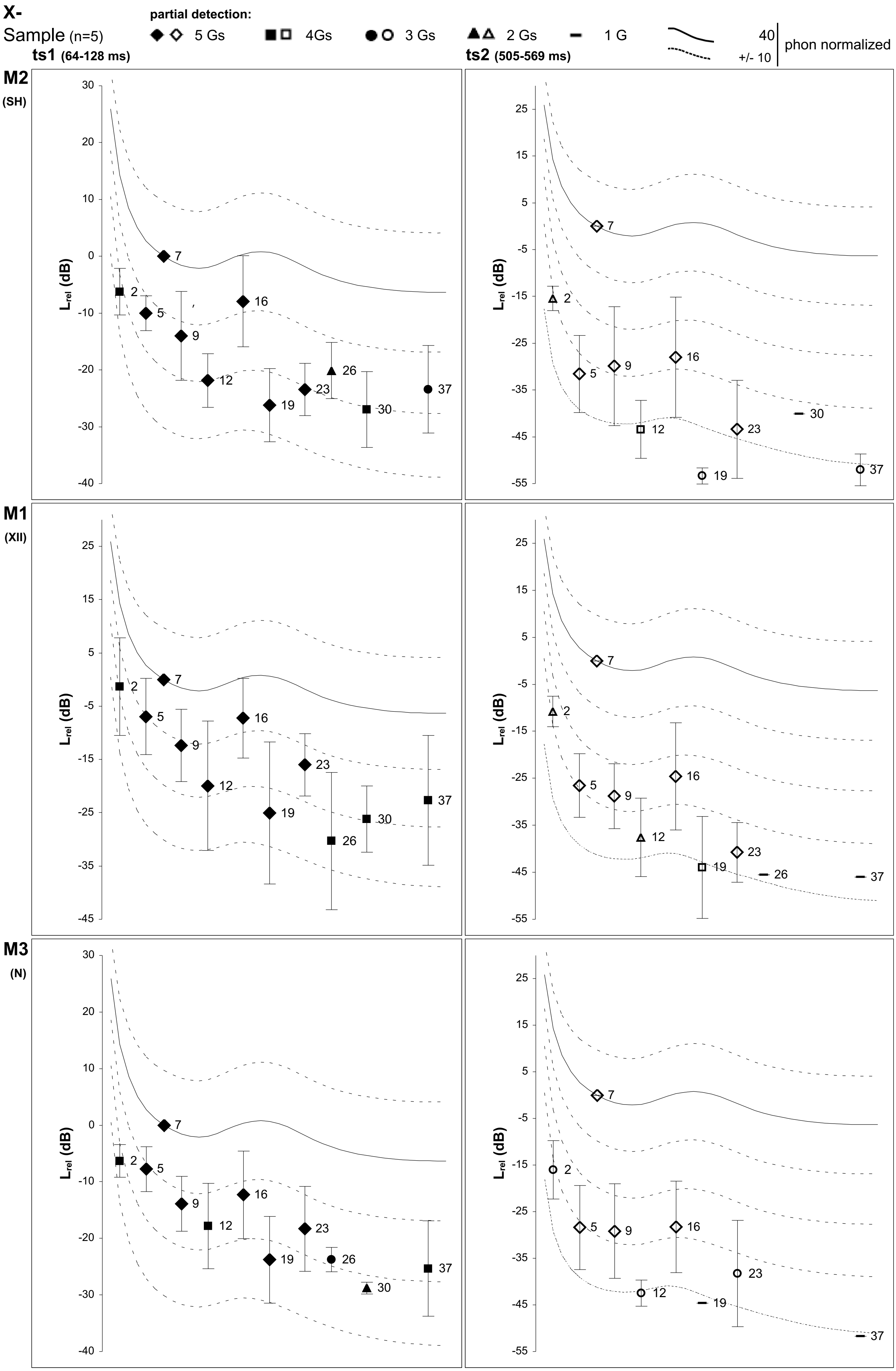
M2 (Sound hole)

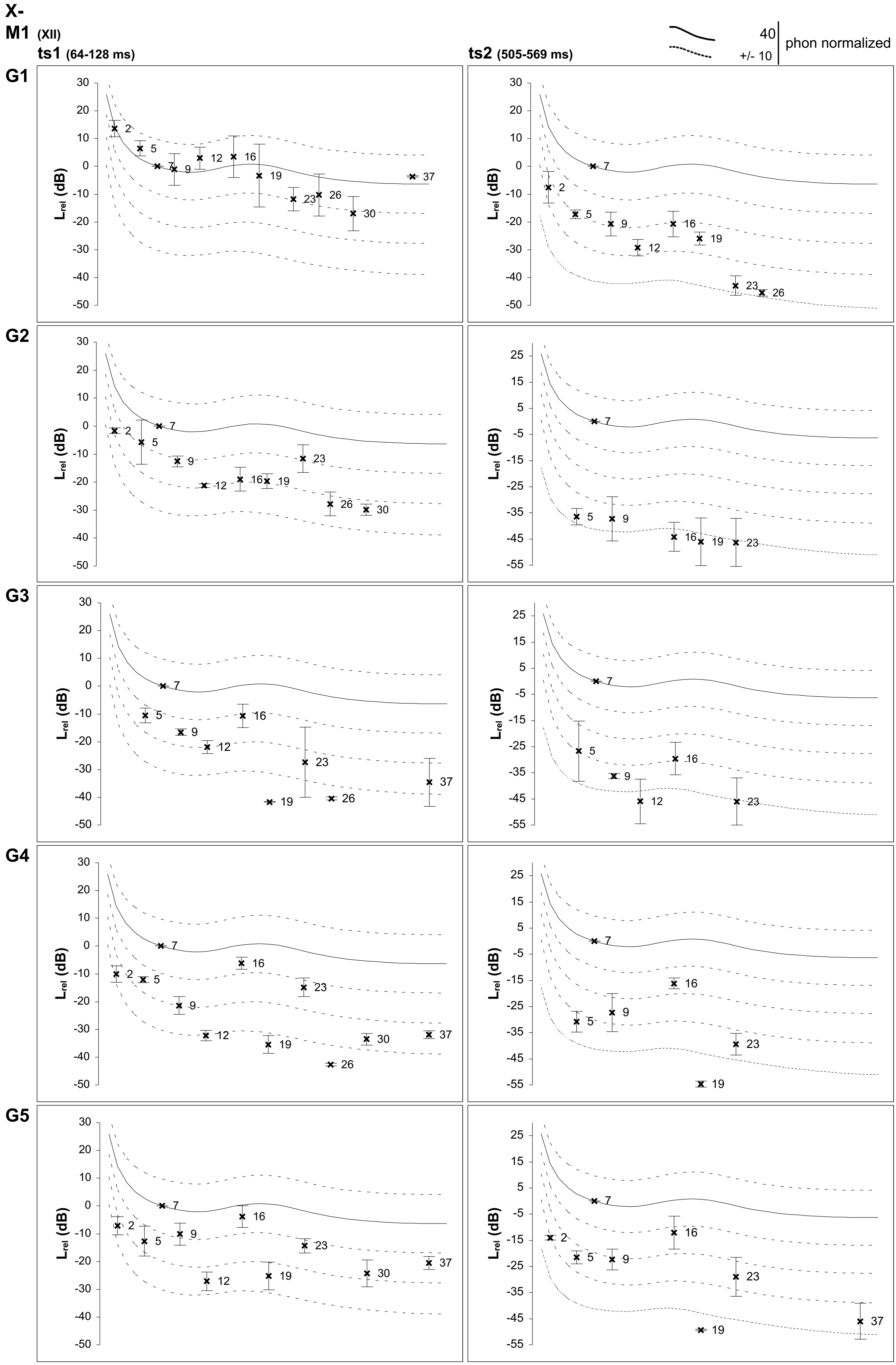


IX.5

M3 (Neck)


40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
G1
G2
G3
G4
G5
L rel (dB)

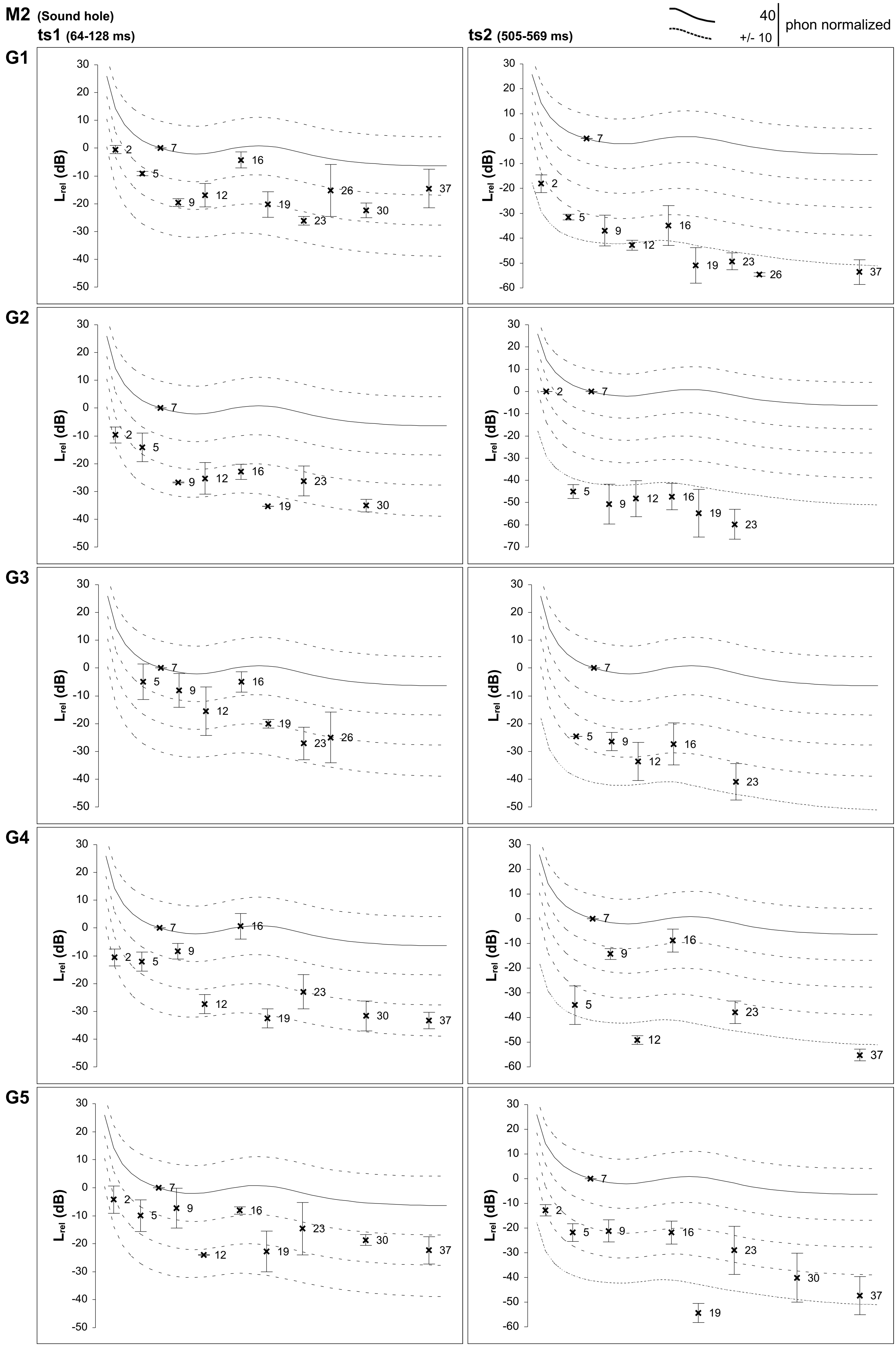

X-
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_rel (dB)


X-
M1 (XII)
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
Lrel (dB)

X-

M2 (Sound hole)

ts1 (64-128 ms) **ts2** (505-569 ms)



X-

M3 (Neck)

ts1 (64-128 ms) **ts2** (505-569 ms)

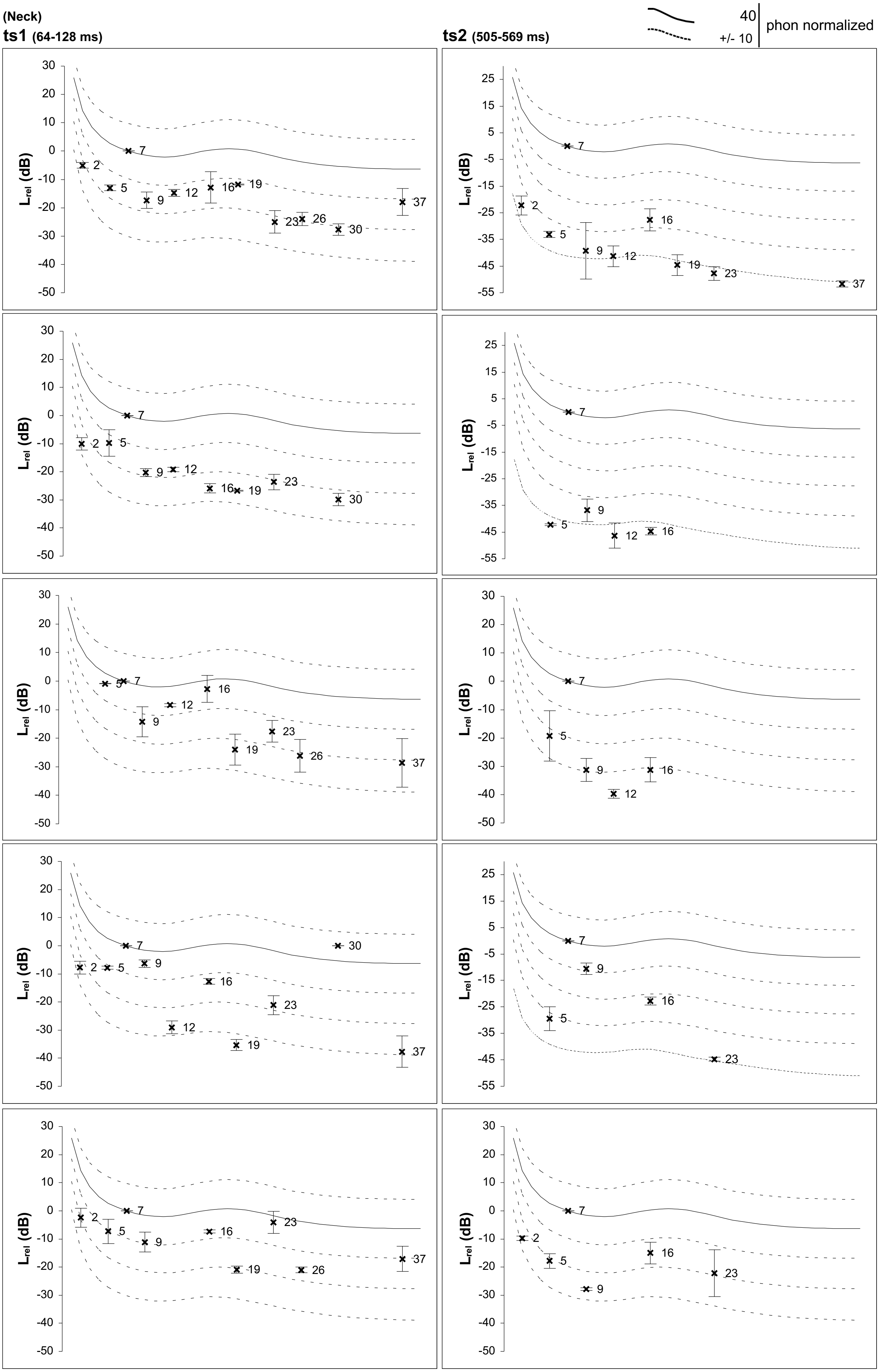
G1

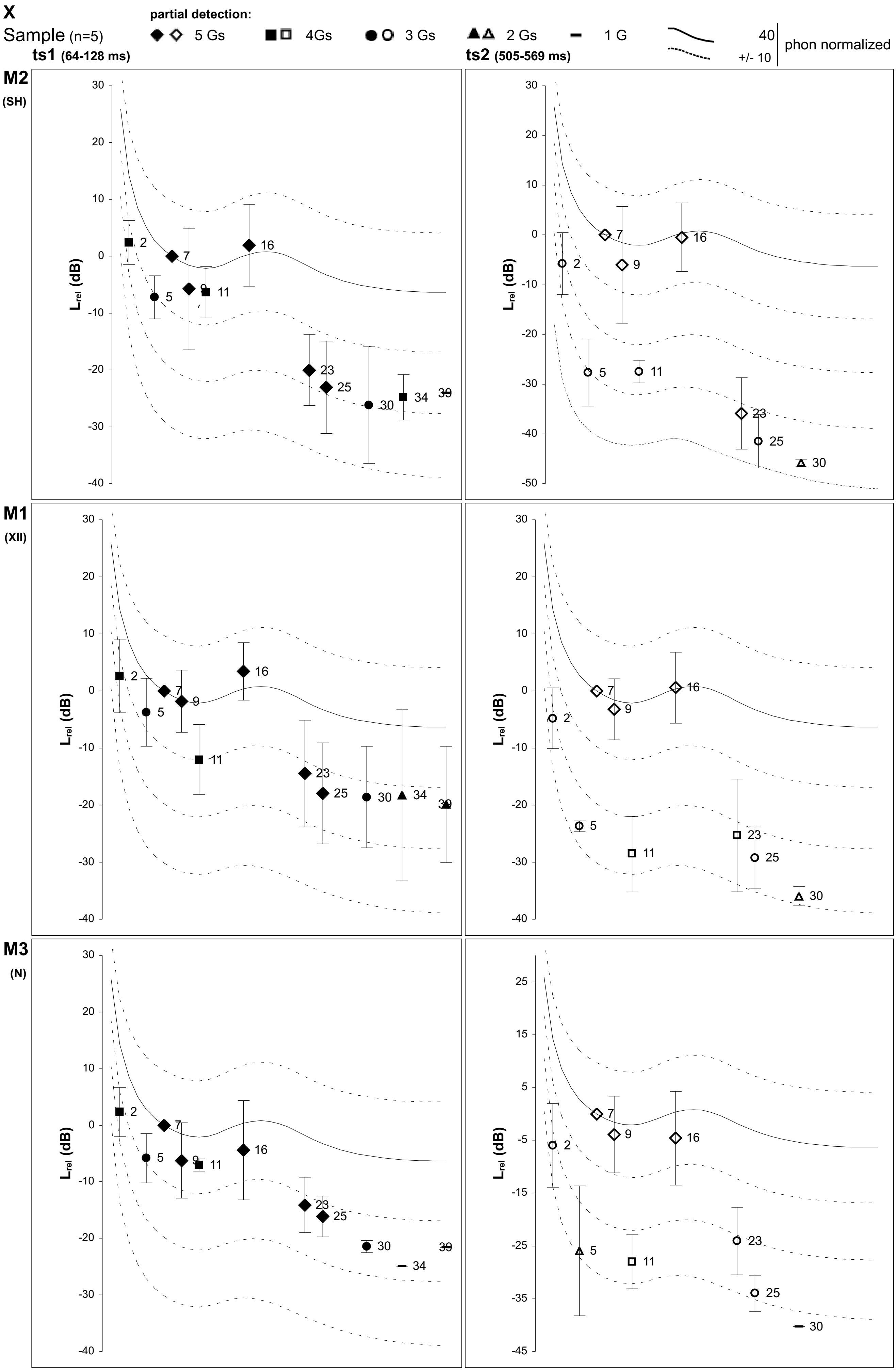
G2

G3

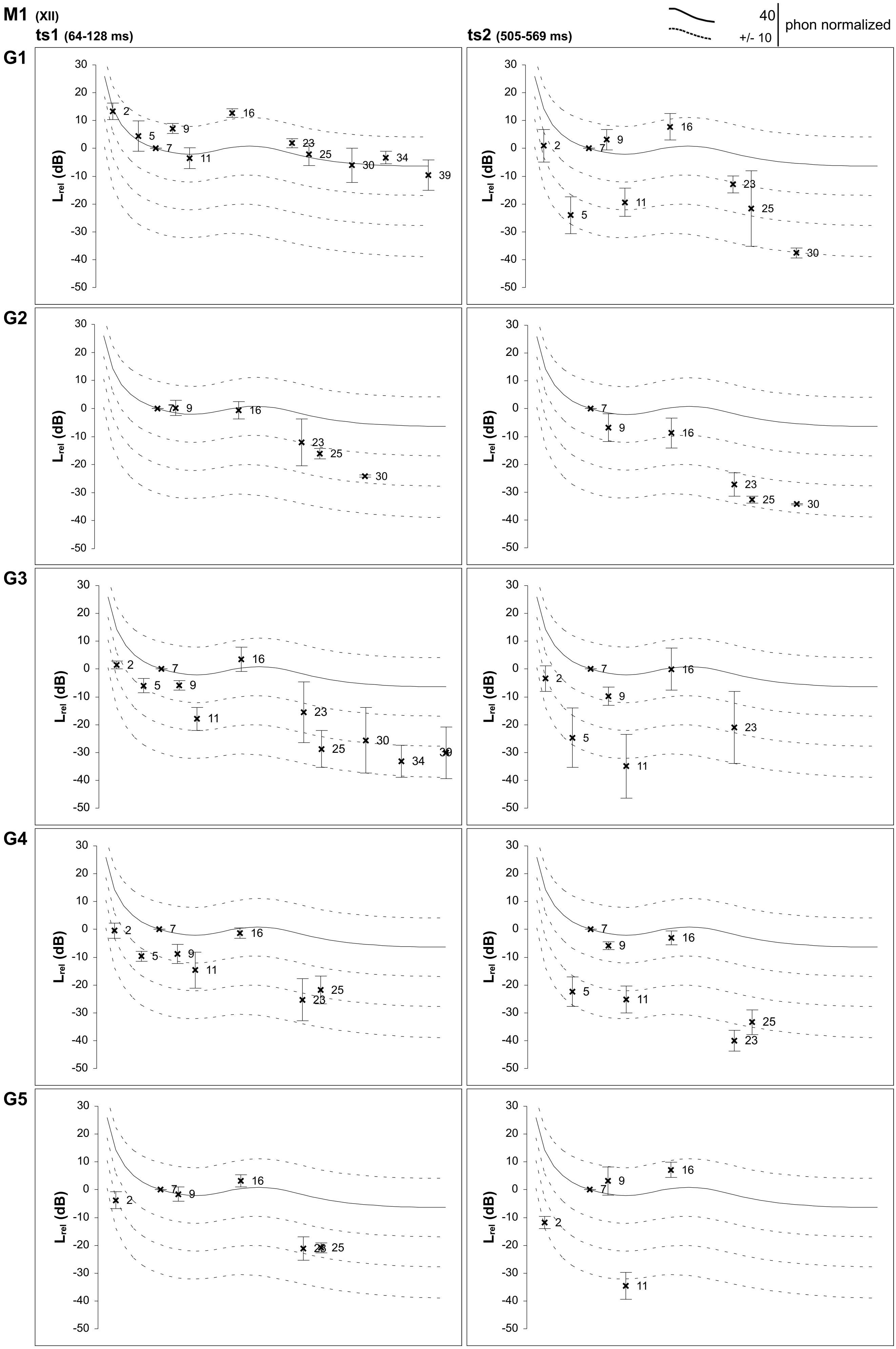
G4

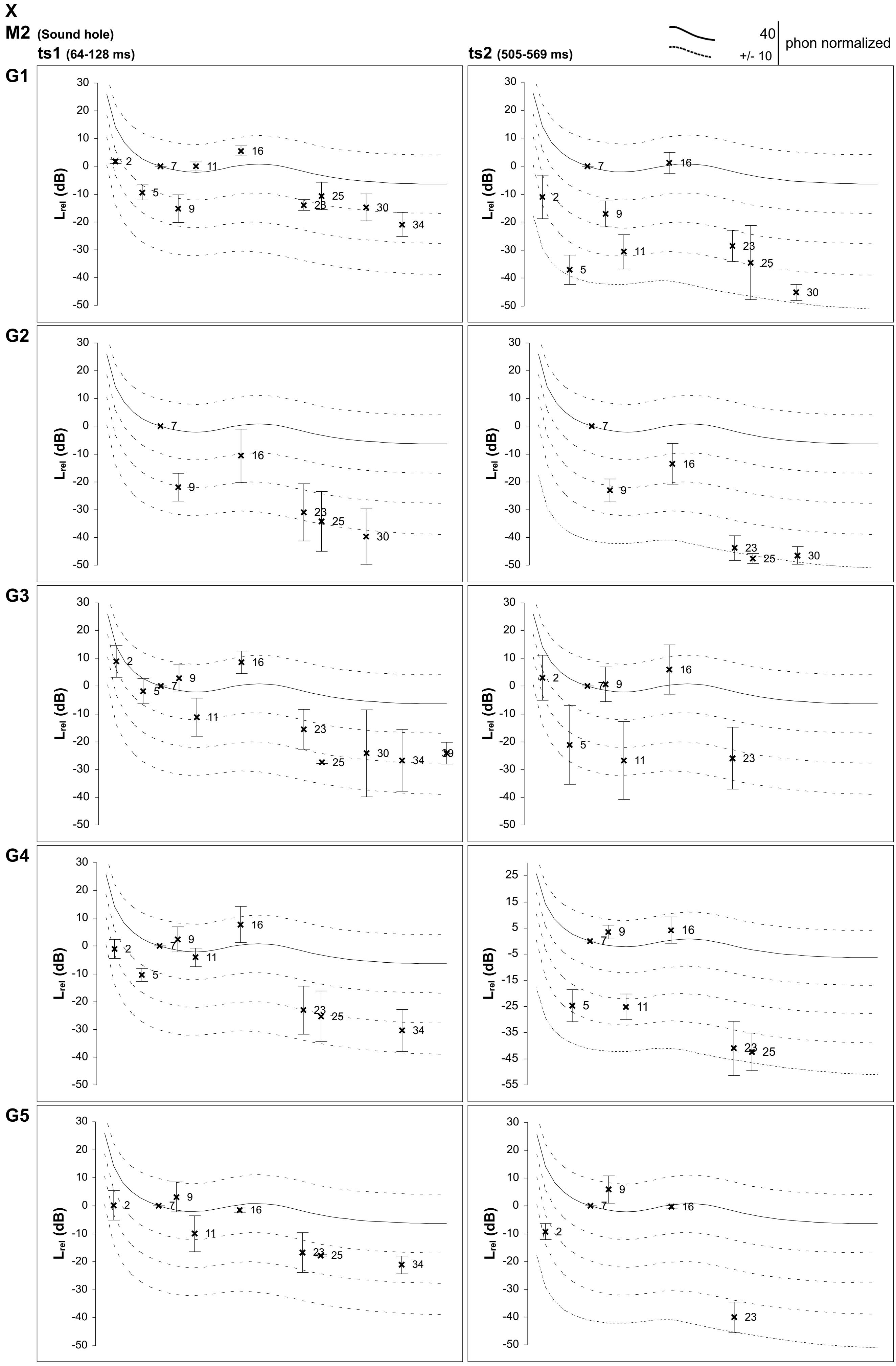
G5




X
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_rel (dB)

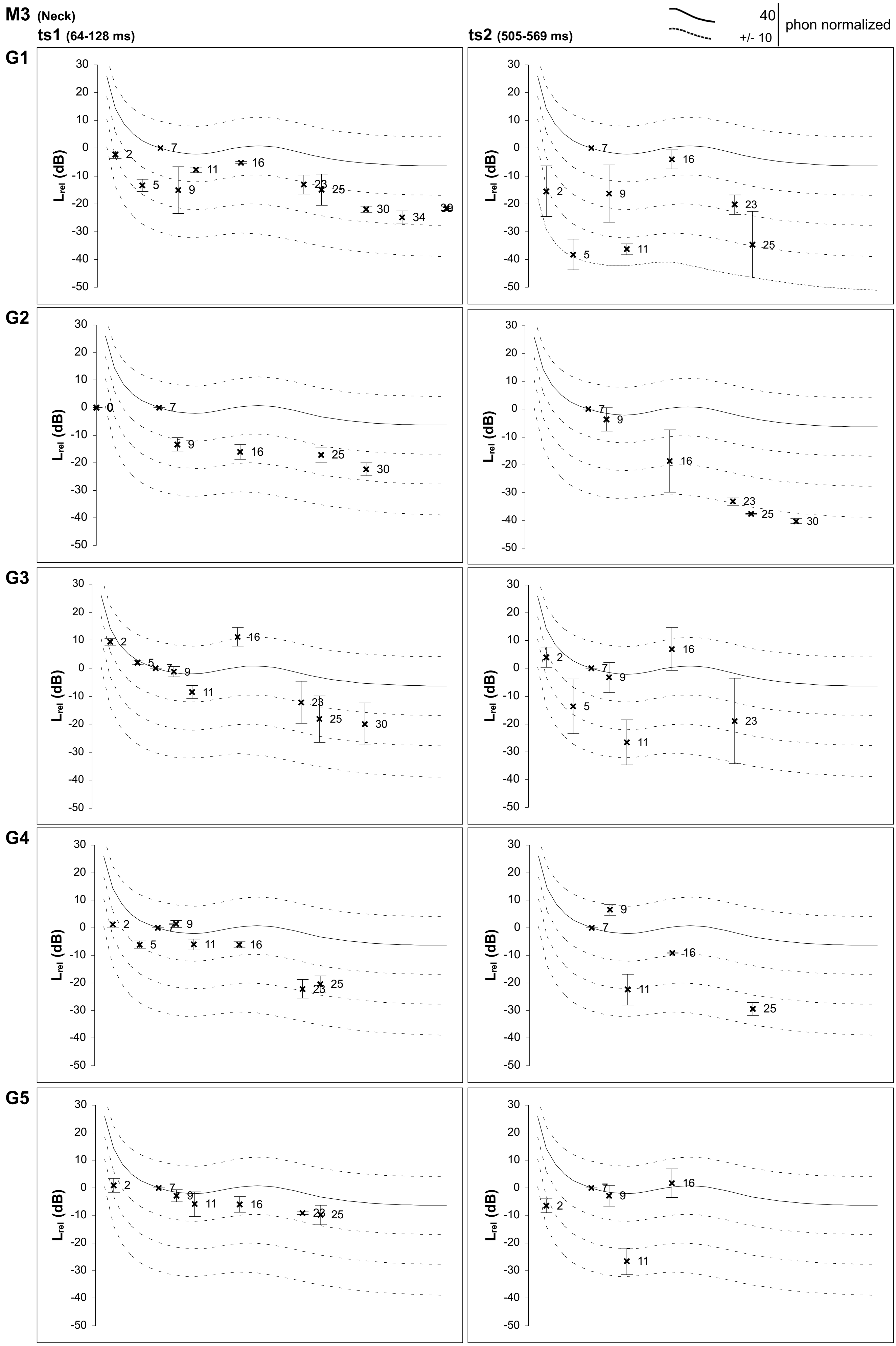
X

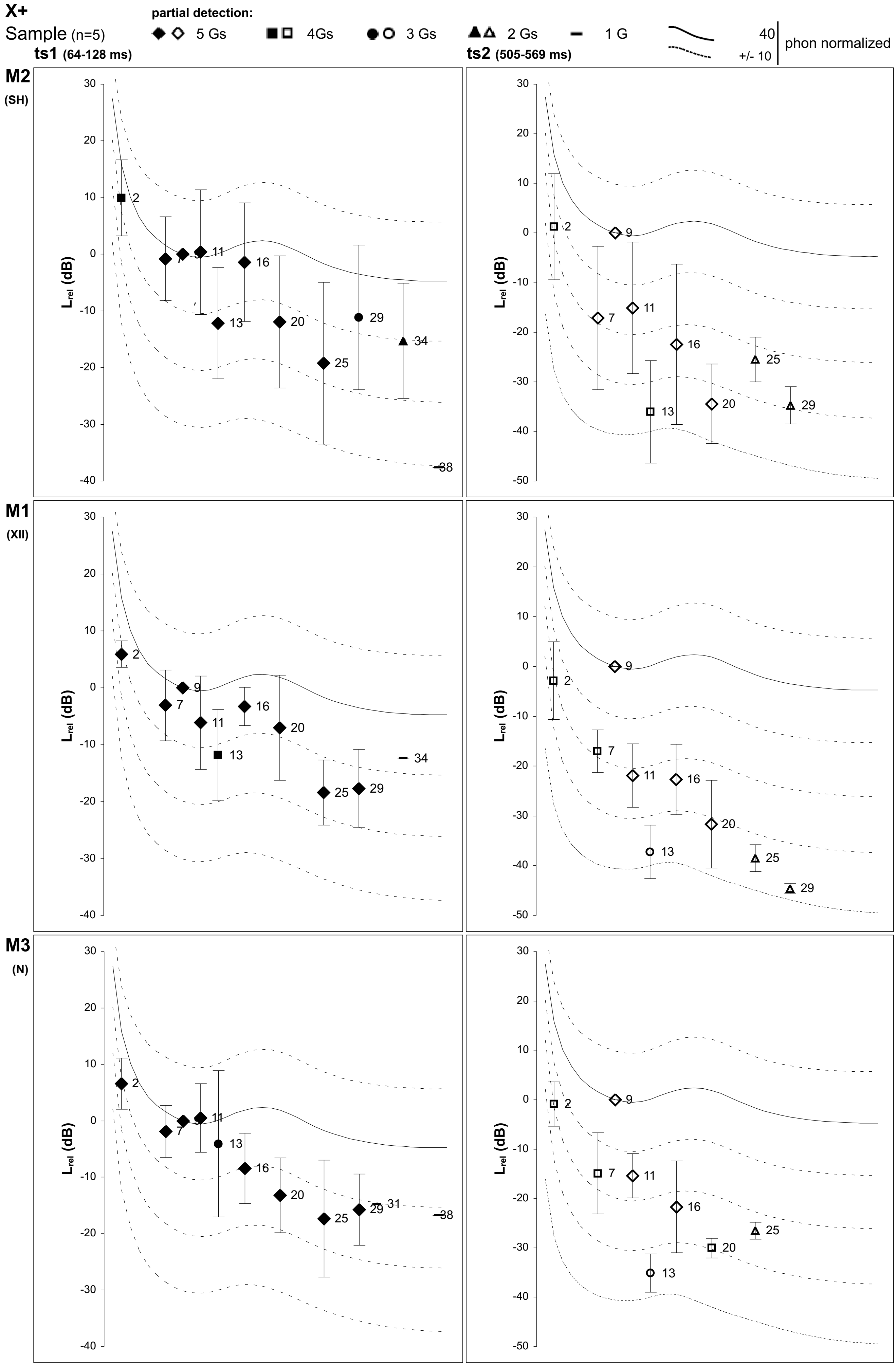

M1 (XII)
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
Lrel (dB)

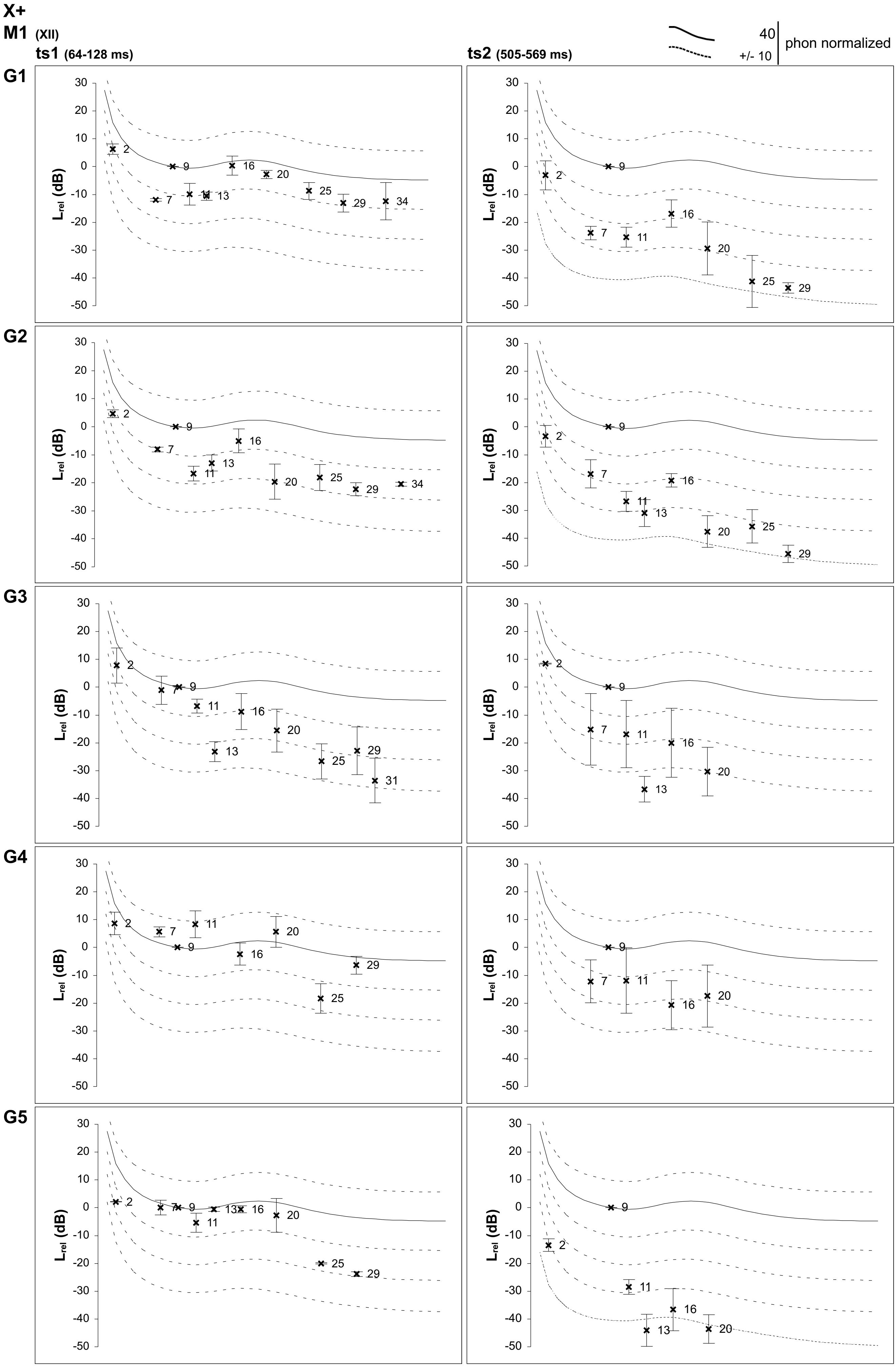

X
M2 (Sound hole)
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
L_{rel} (dB)

X

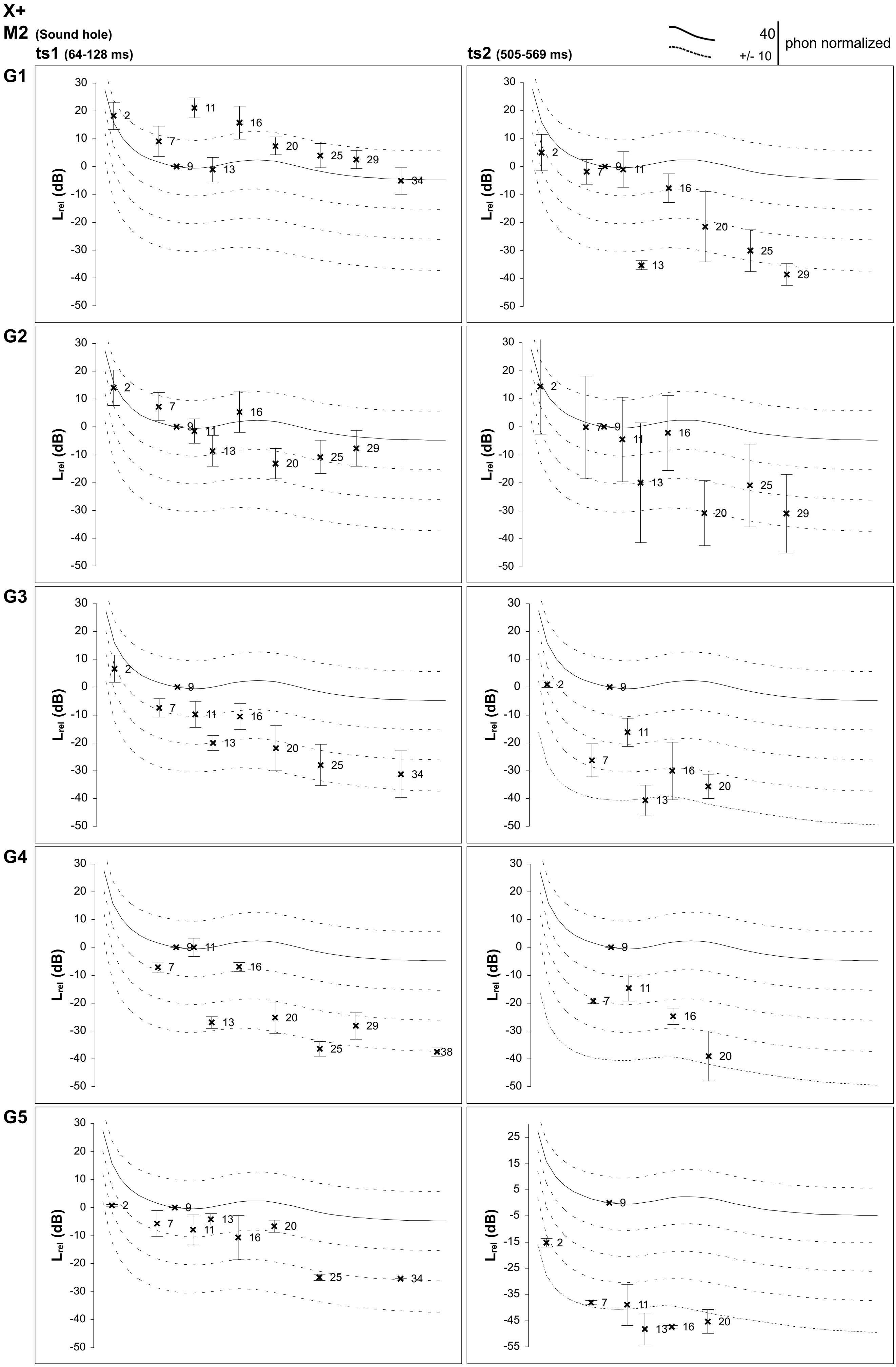
M3 (Neck)

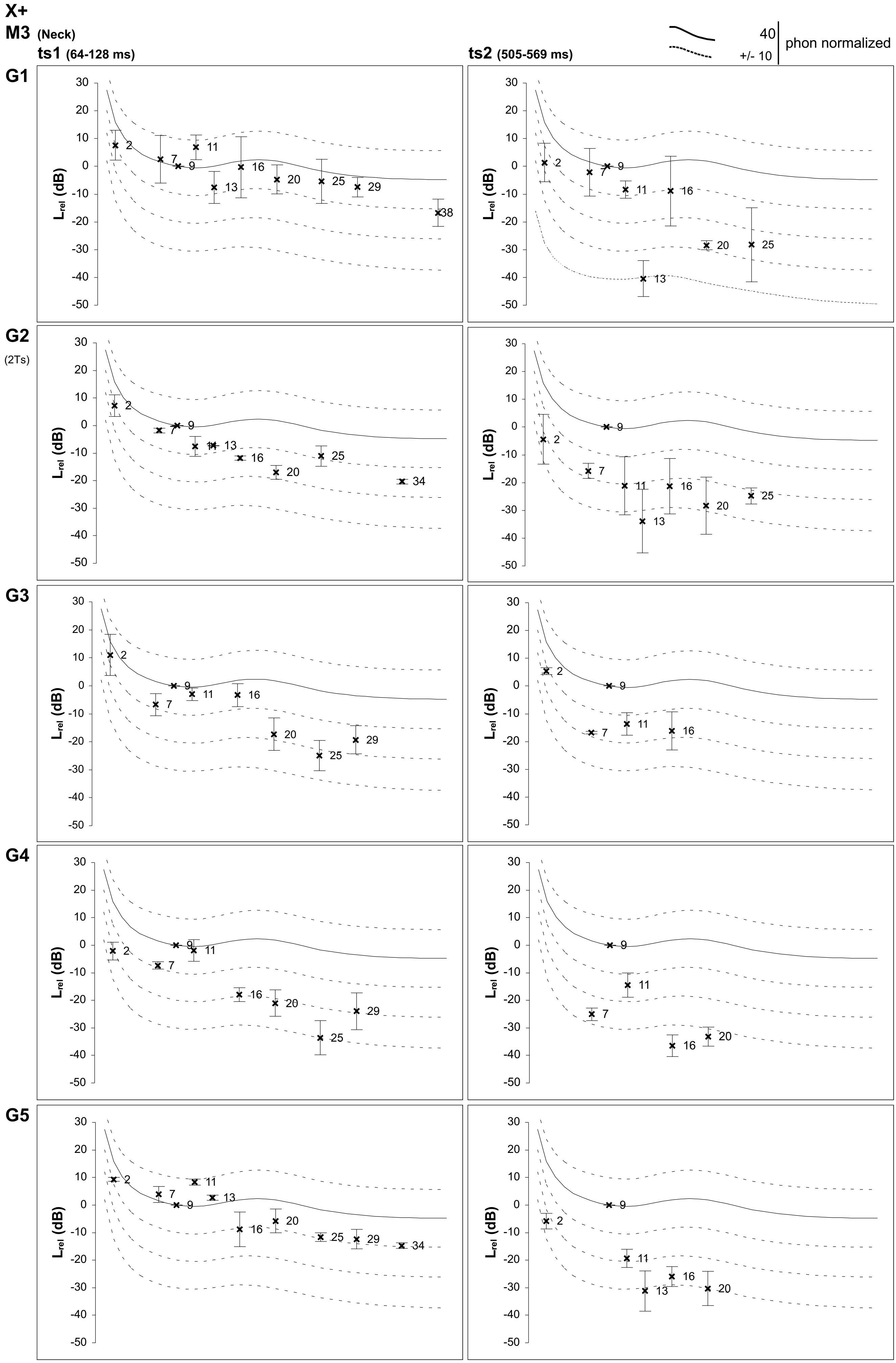

ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
L_rel (dB)

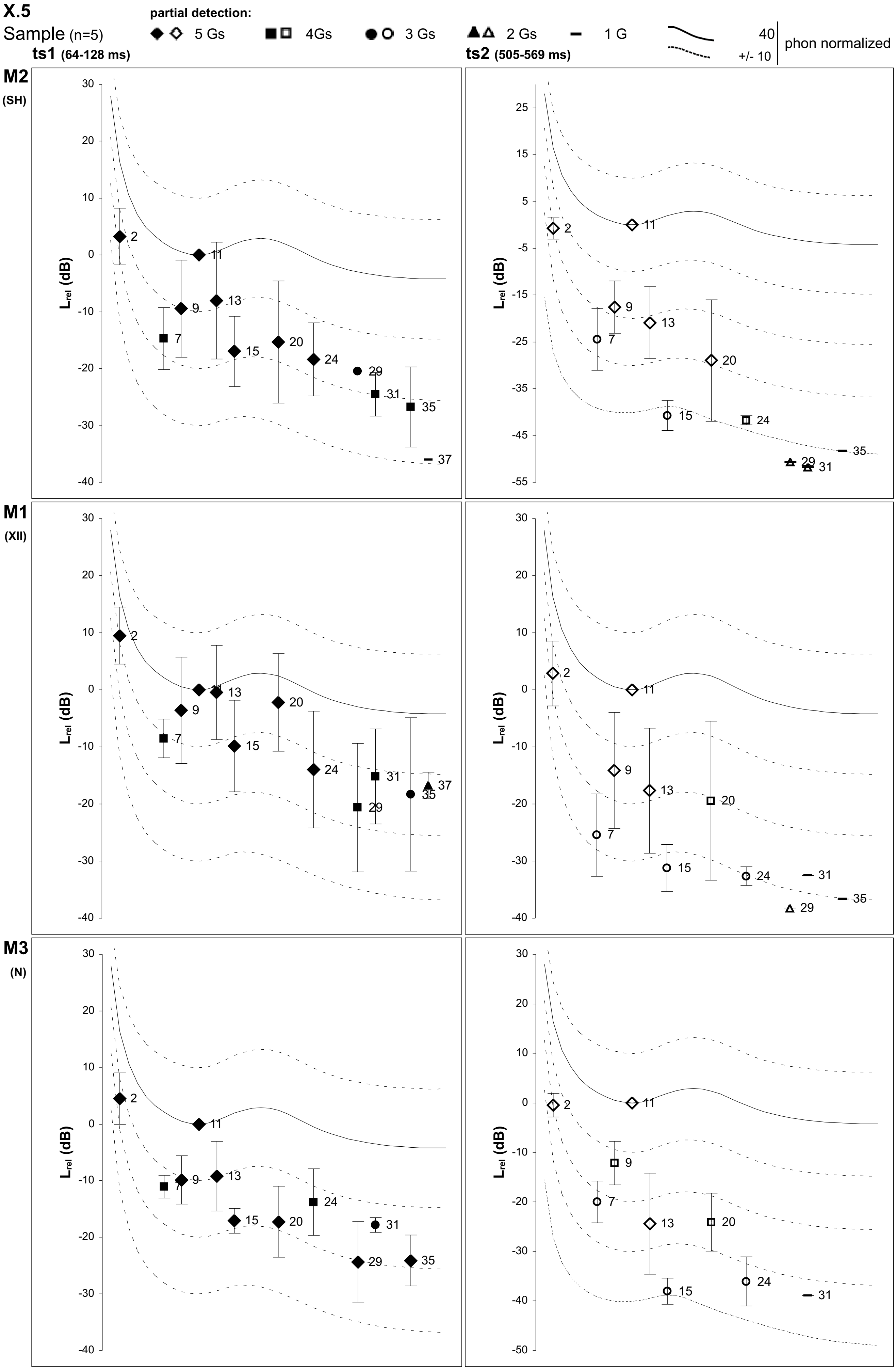

X+
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_{rel} (dB)



X+
M1 (XII)
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
L_rel (dB)
30
20
10
0
-10
-20
-30
-40
-50

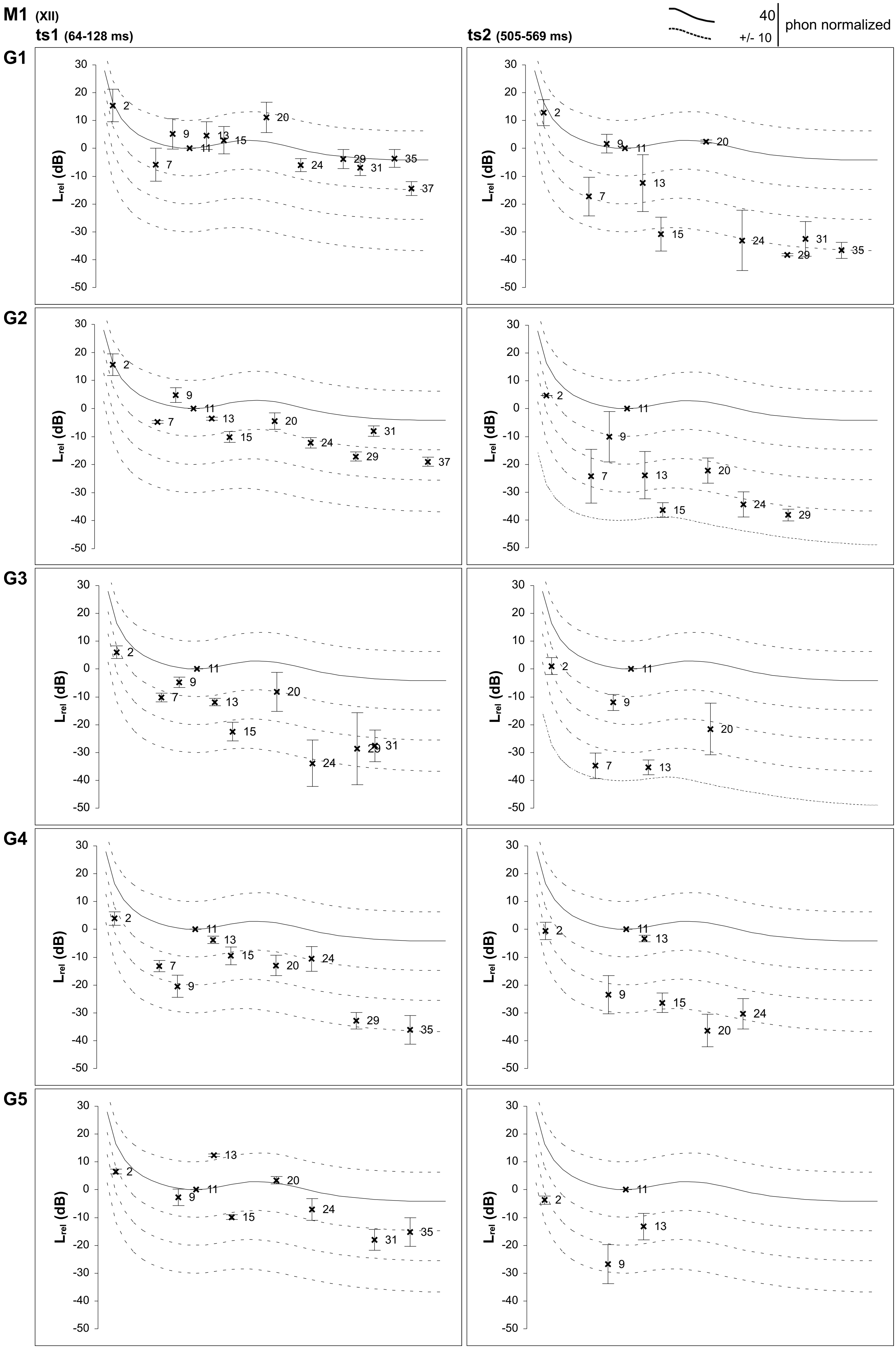

X+
M2 (Sound hole)
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
Lrel (dB)


X+
M3 (Neck)
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
(2Ts)
G3
G4
G5
Lrel (dB)


X.5
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_rel (dB)

X.5

M1 (XII)


ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
L_rel (dB)

X.5

M2 (Sound hole)

ts1 (64-128 ms) **ts2** (505-569 ms)

40 / +/- 10 phon normalized

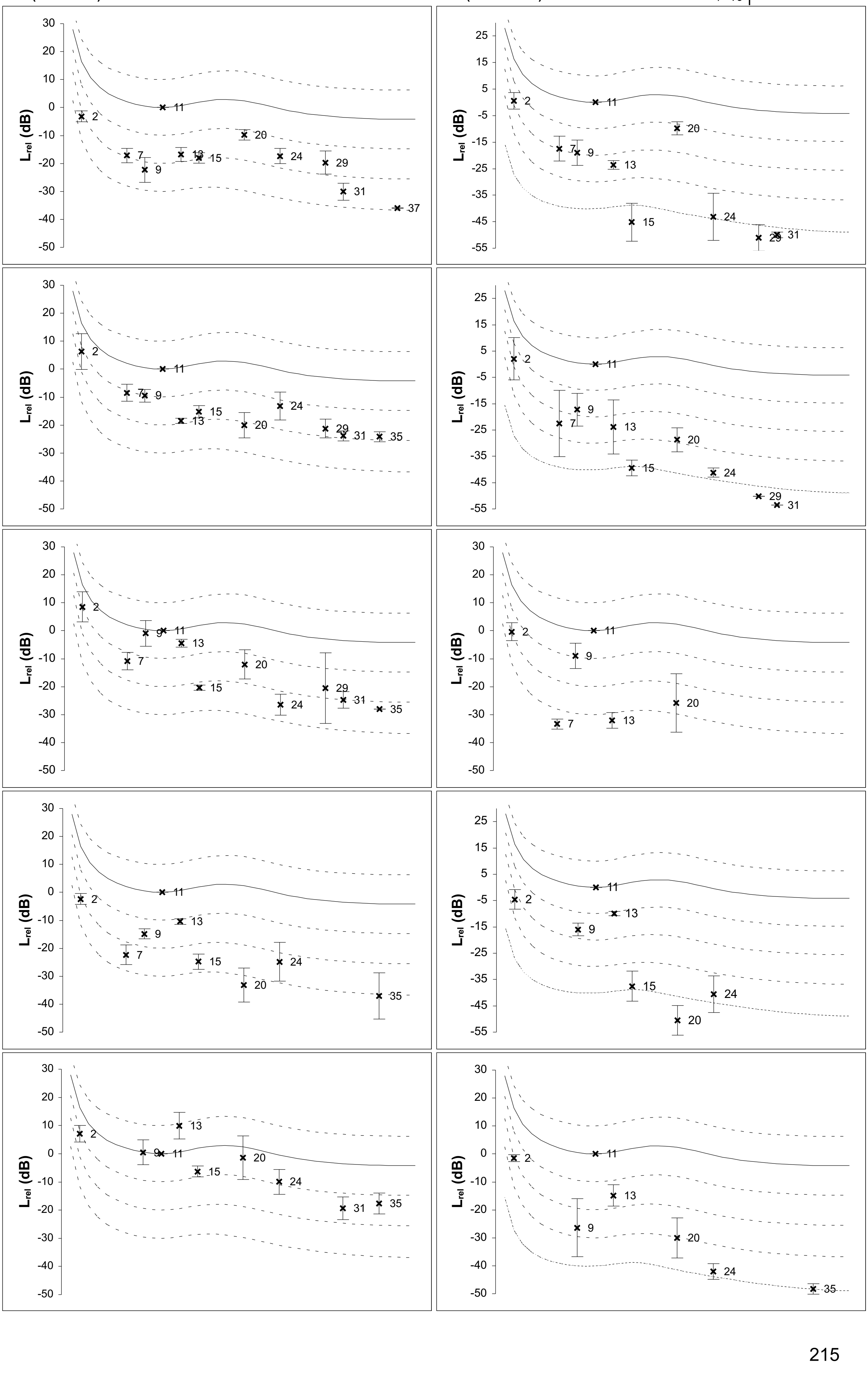
G1

G2

G3

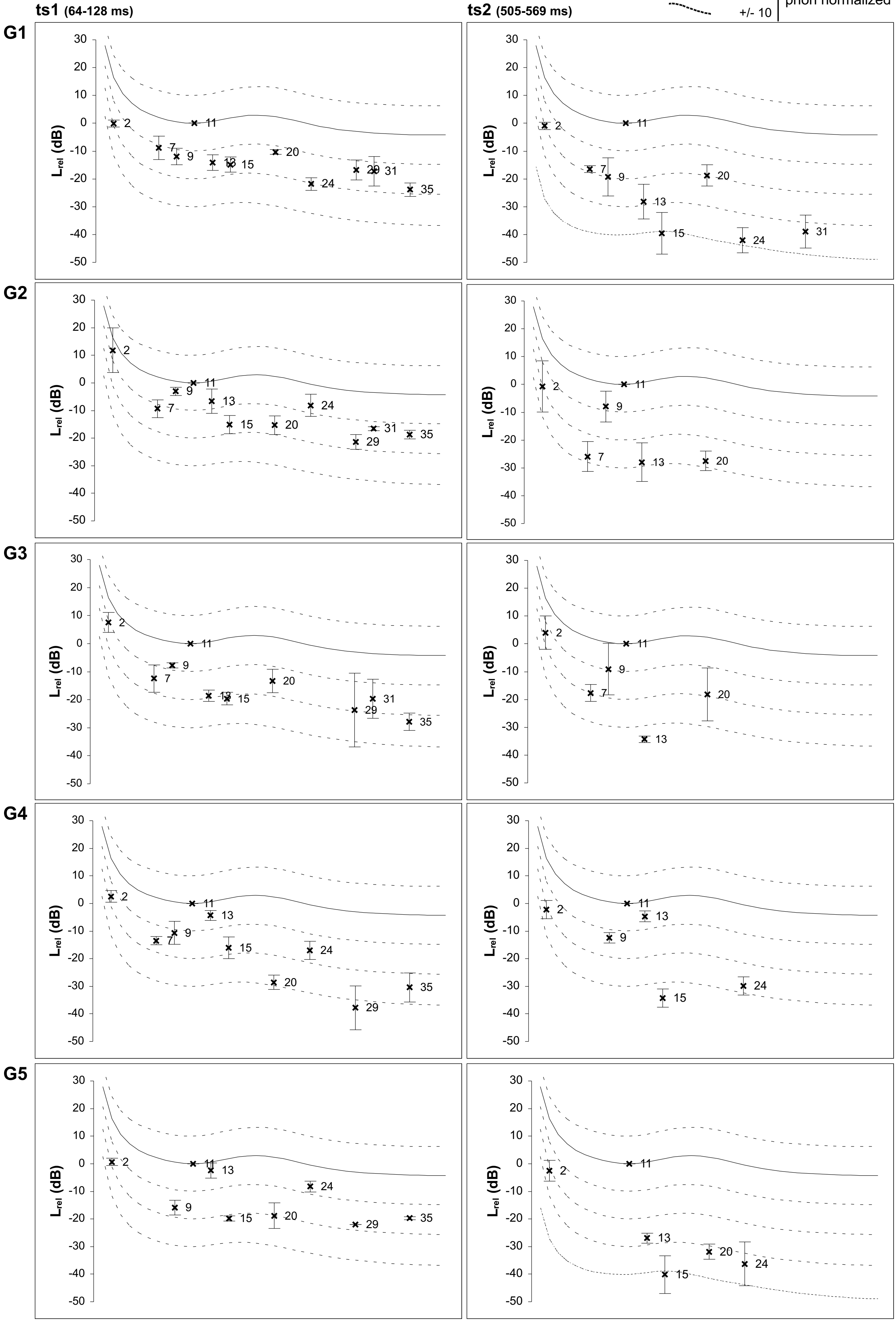
G4

G5

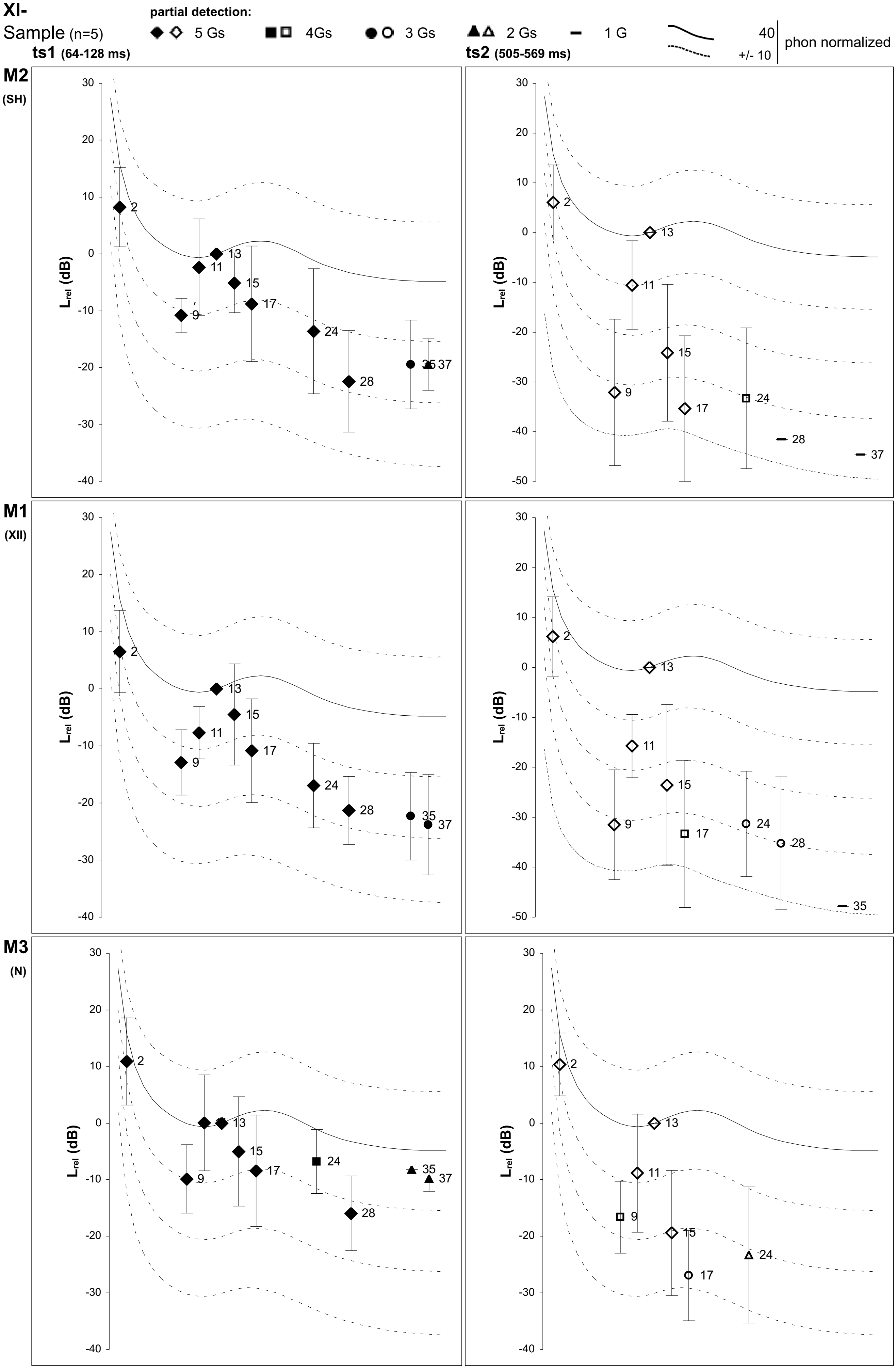


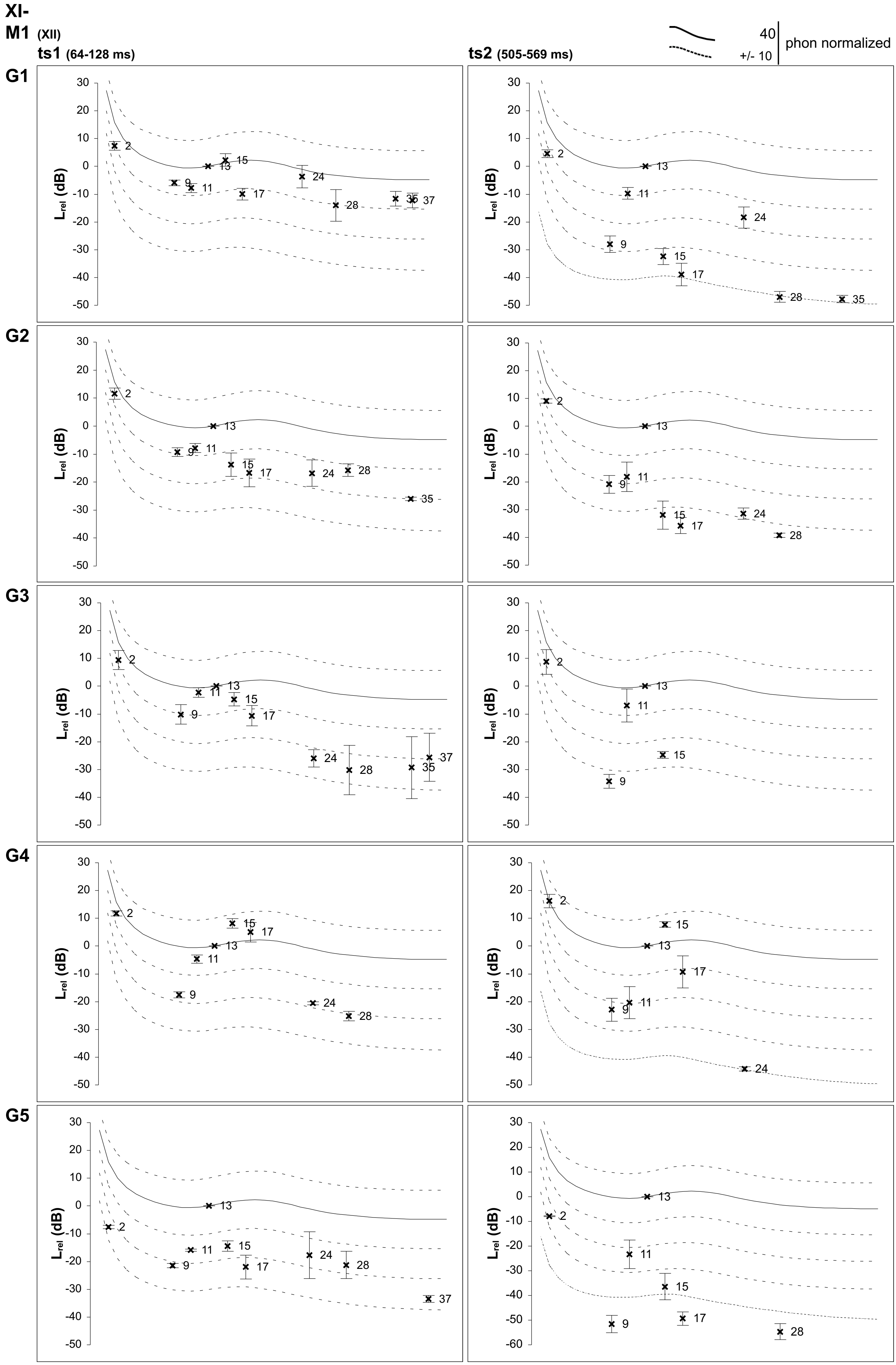
X.5

M3 (Neck)

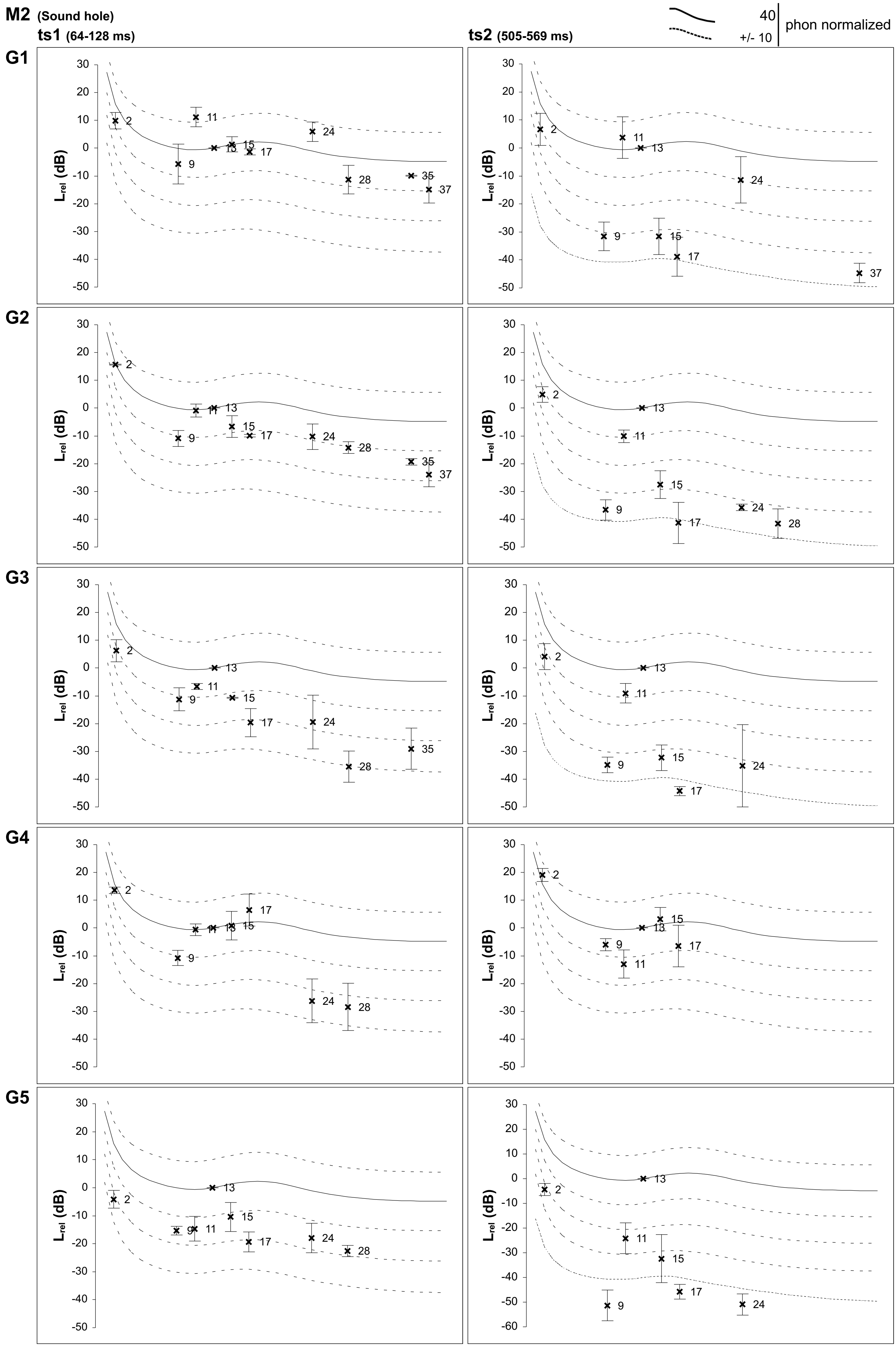


ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
L$_{rel}$ (dB)

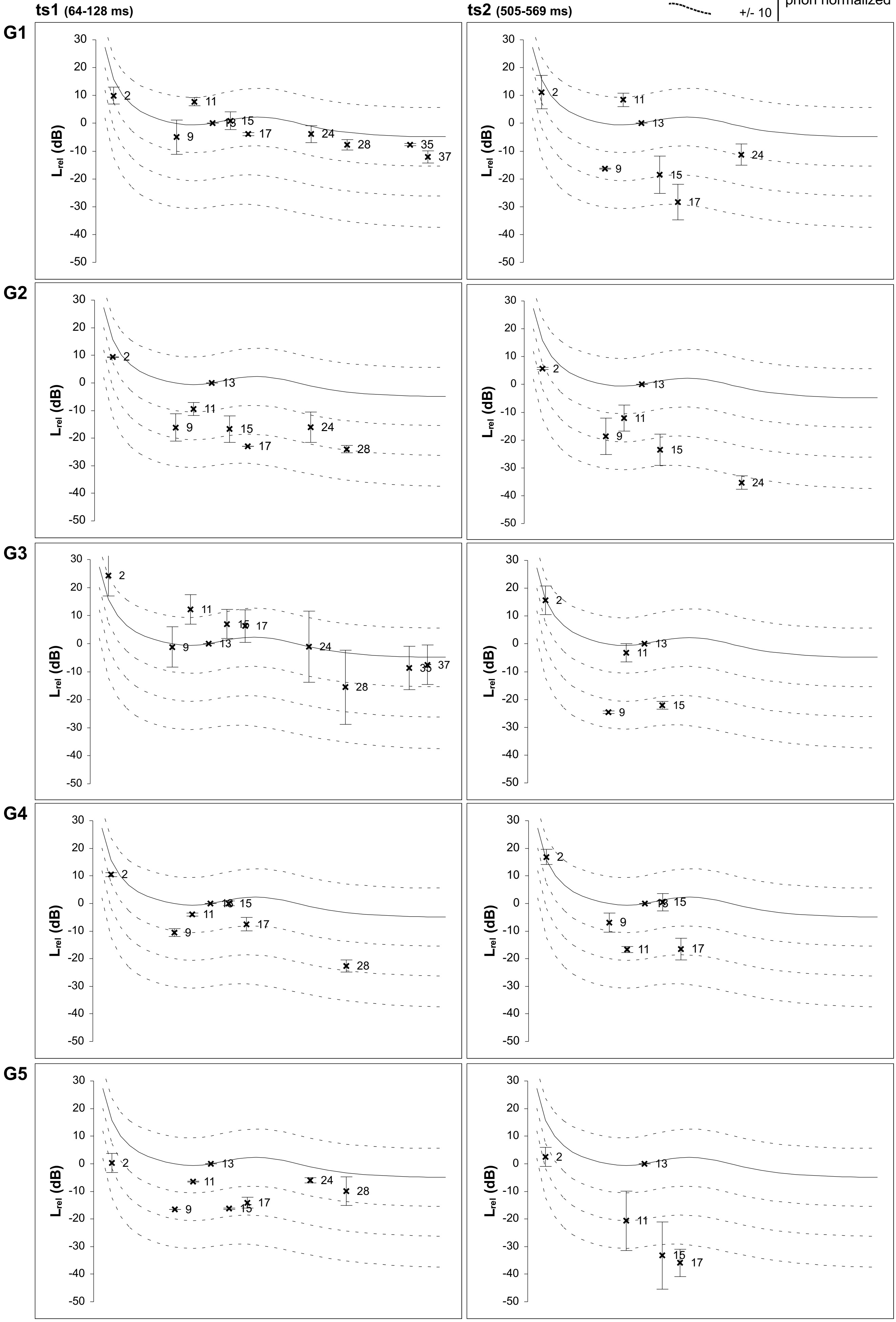

XI-
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_{rel} (dB)
30
20
10
0
-10
-20
-30
-40
-50
2
9
11
13
15
17
24
28
35
37


XI-
M1 (XII)
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
L_rel (dB)

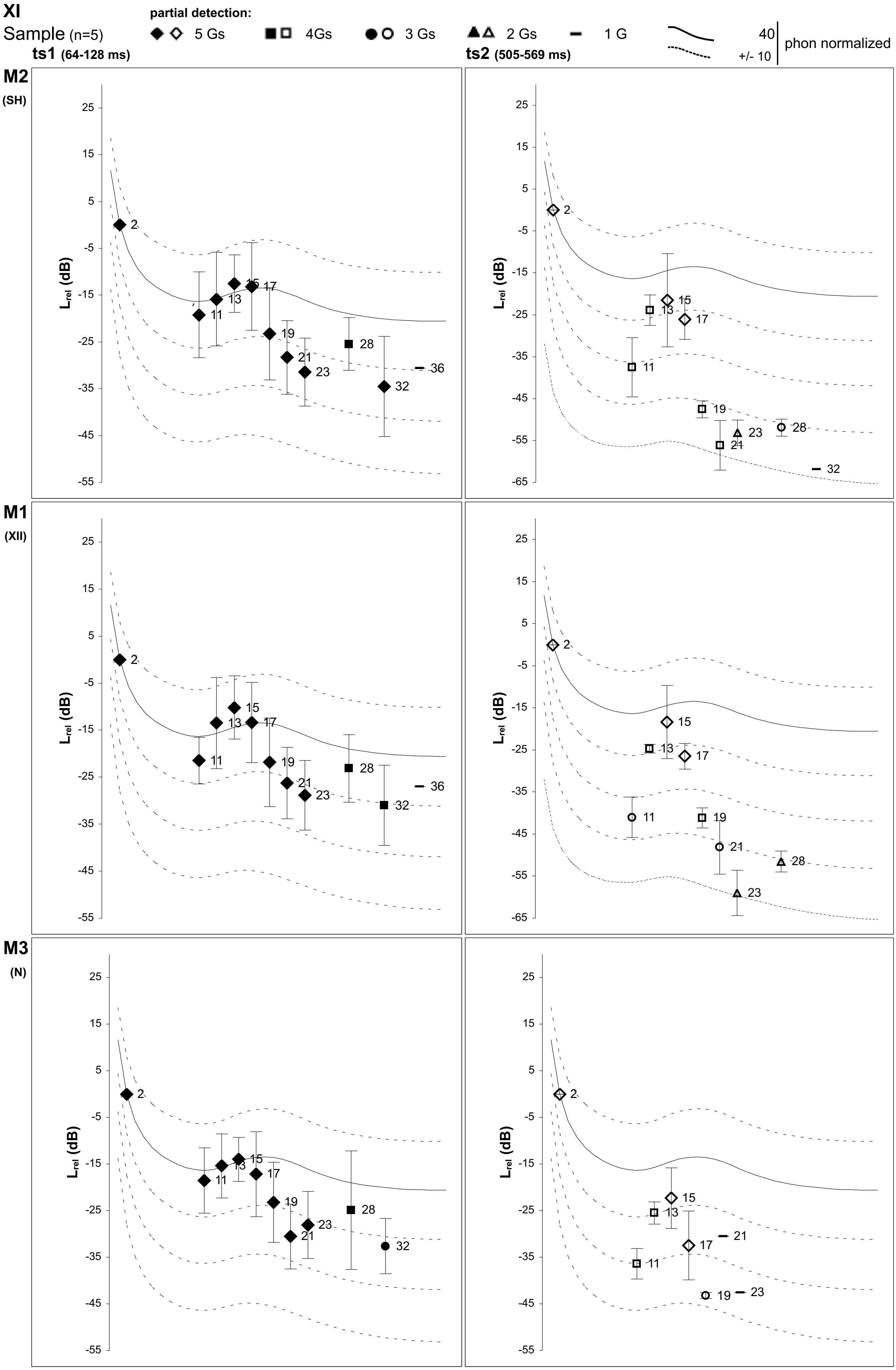
XI-
M2 (Sound hole)



XI-M3 (Neck)



ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
Lrel (dB)


XI
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_rel (dB)

XI

M1 **(XII)**

ts1 **(64-128 ms)** **ts2** **(505-569 ms)**

40 | phon normalized
+/- 10 |

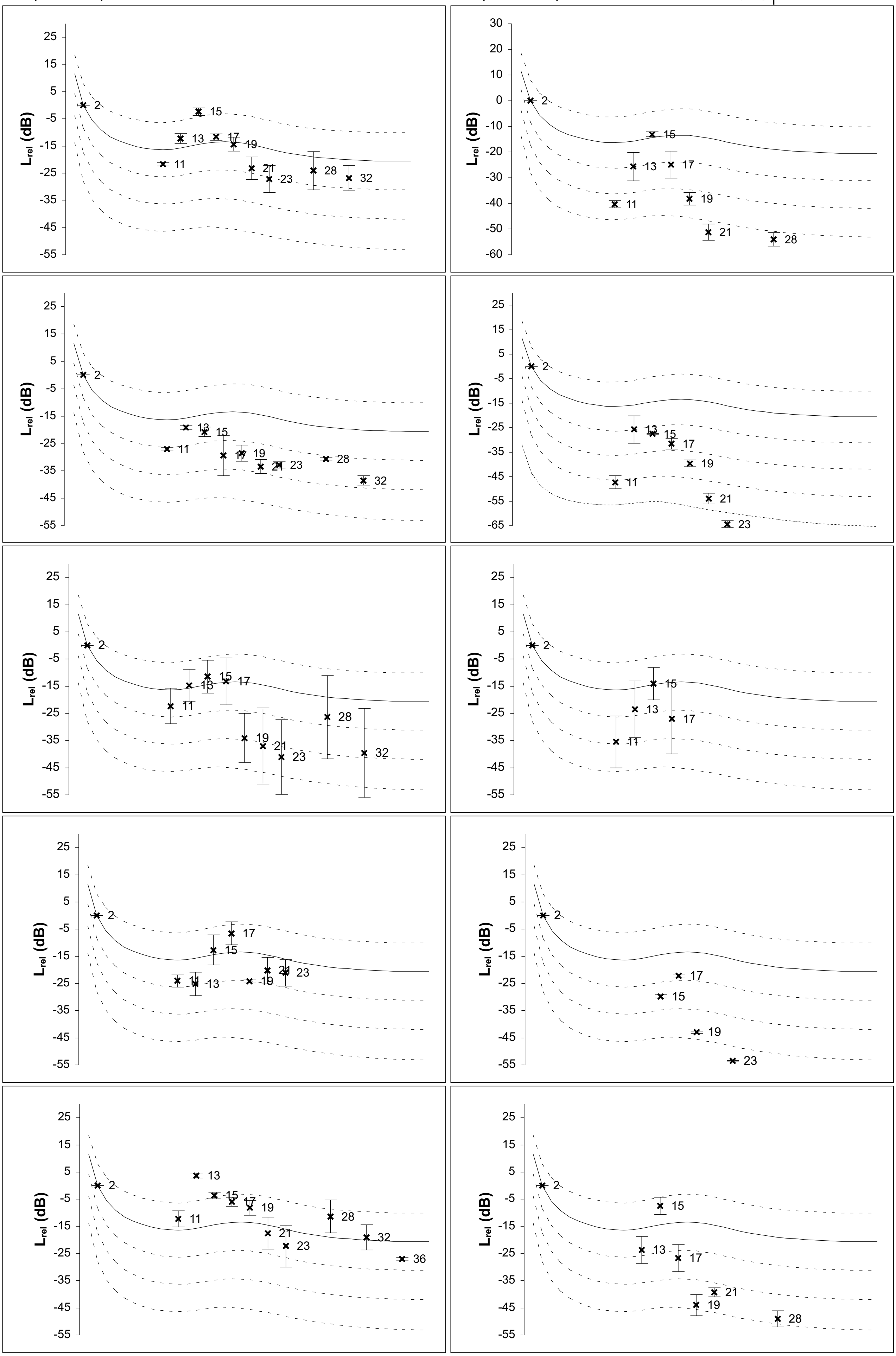
G1

G2
(2Ts)

G3

G4

G5



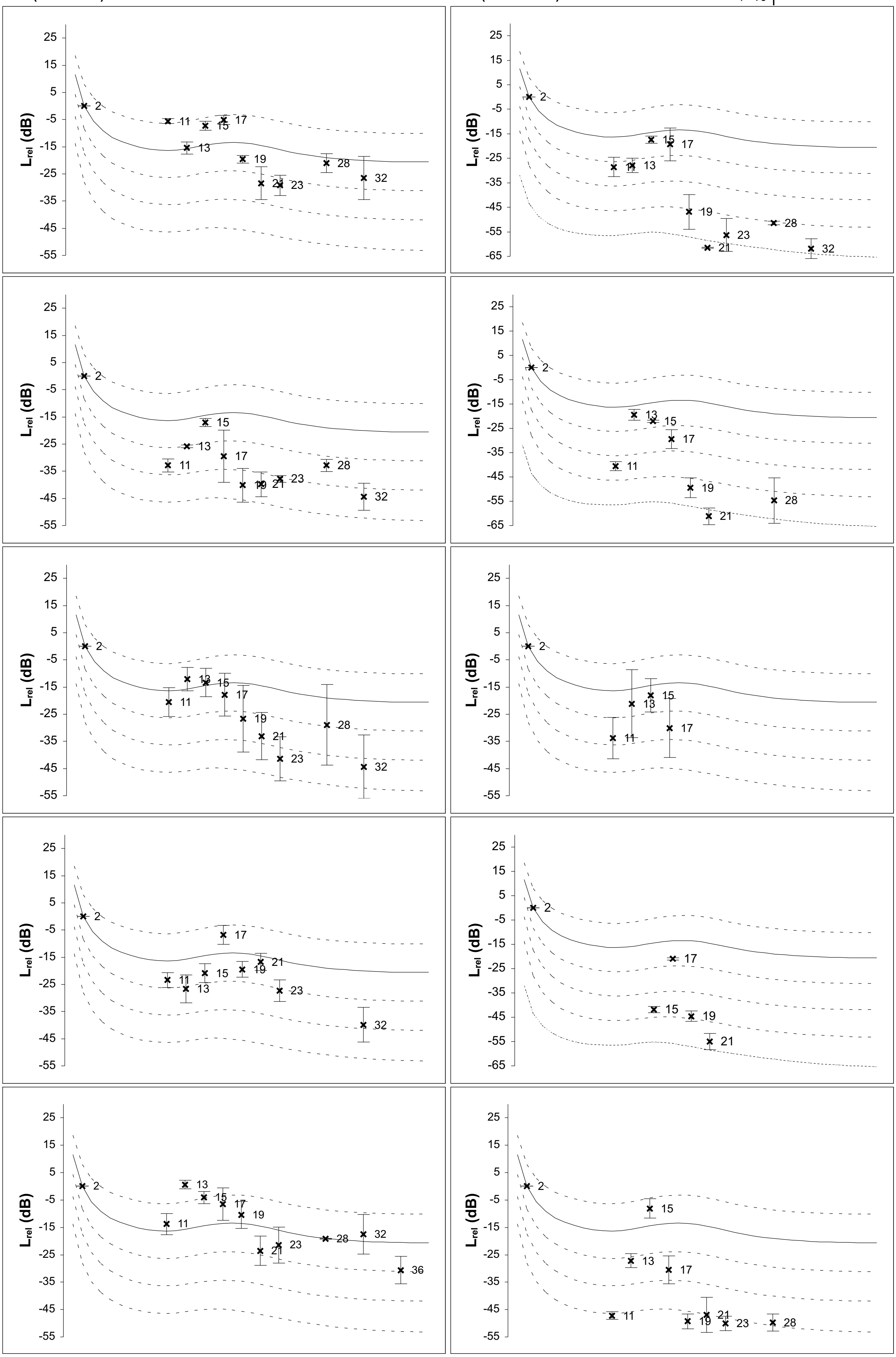
XI

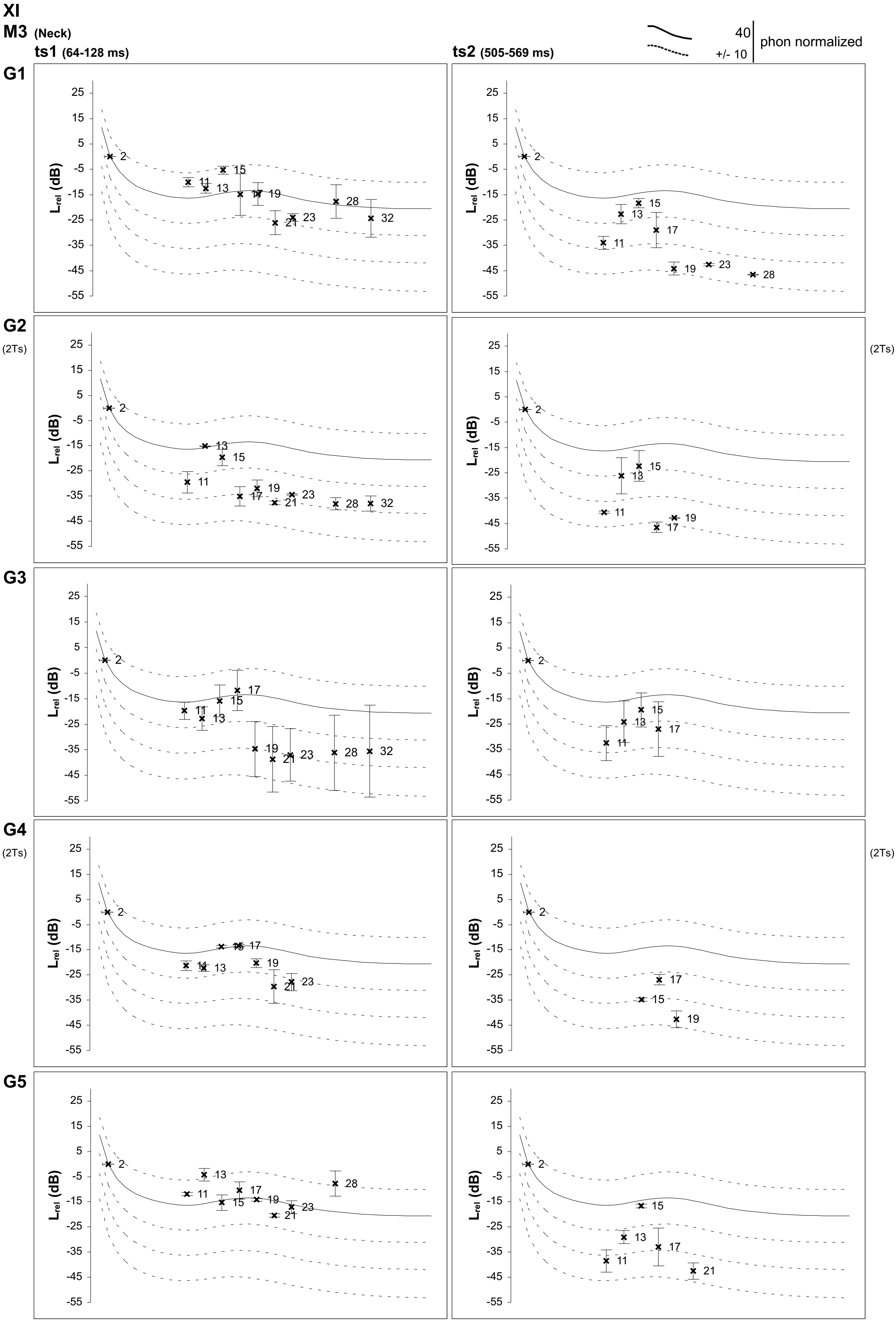
M2 **(Sound hole)**

ts1 **(64-128 ms)** | **ts2** **(505-569 ms)**

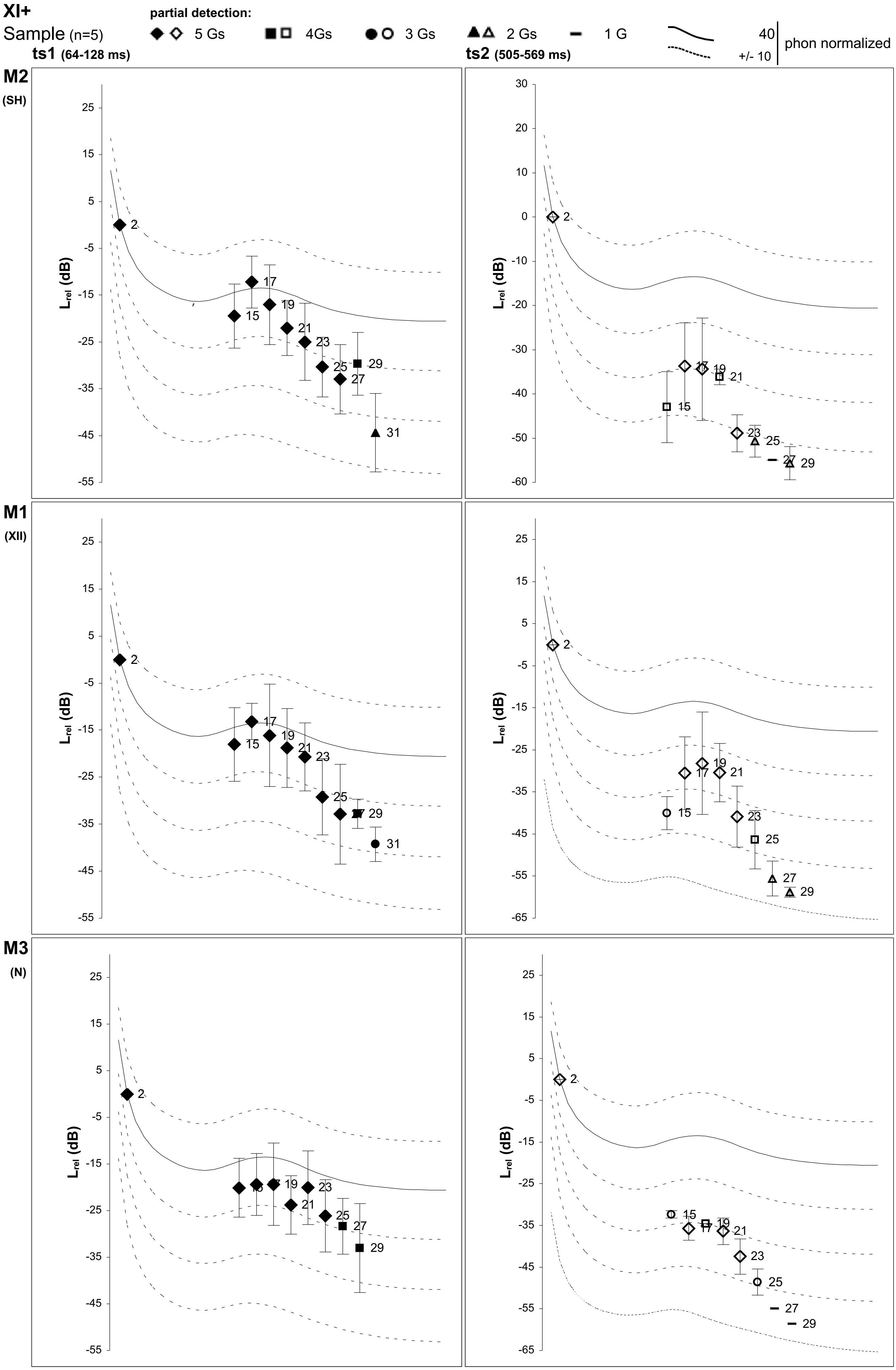
40 | +/- 10 — phon normalized

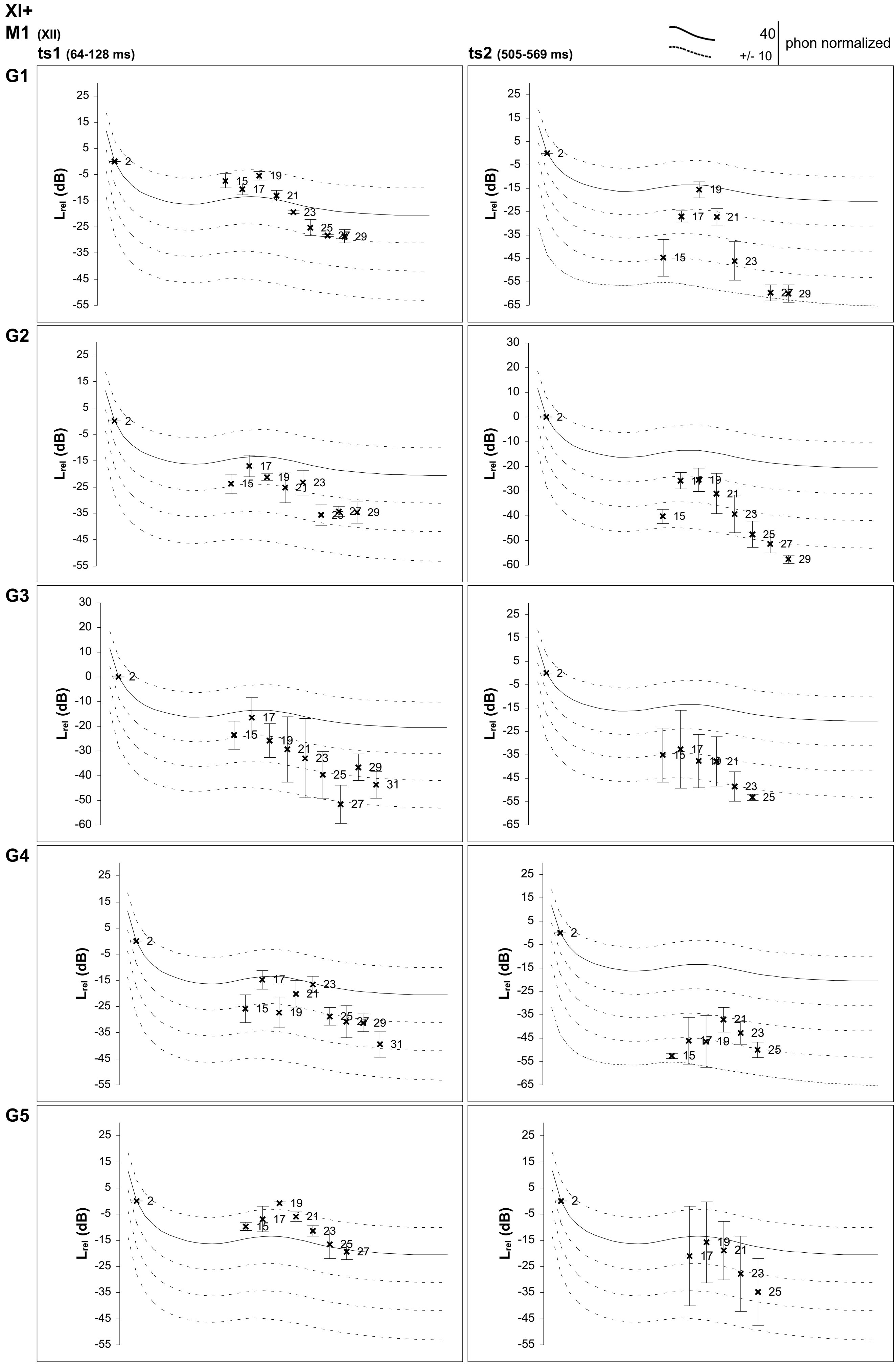
G1 · **G2** (2Ts) · **G3** · **G4** · **G5**





XI
M3 (Neck)
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
(2Ts)
G3
G4
(2Ts)
G5
Lrel (dB)


XI+
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_rel (dB)


XI+
M1 (XII)
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
Lrel (dB)

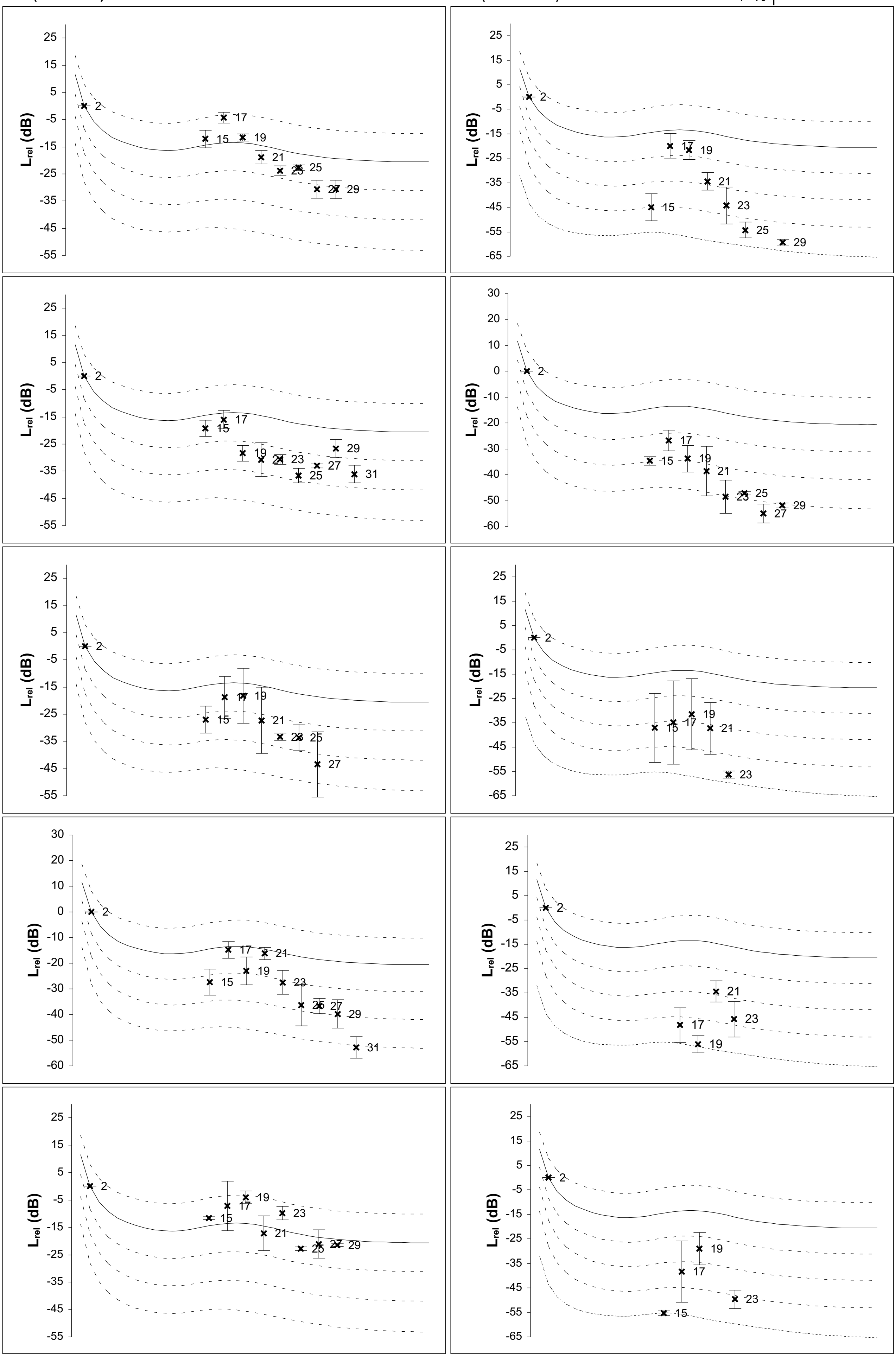
XI+

M2 (Sound hole)

ts1 (64-128 ms) **ts2** (505-569 ms)

40 / +/- 10 phon normalized

G1 G2 G3 G4 G5



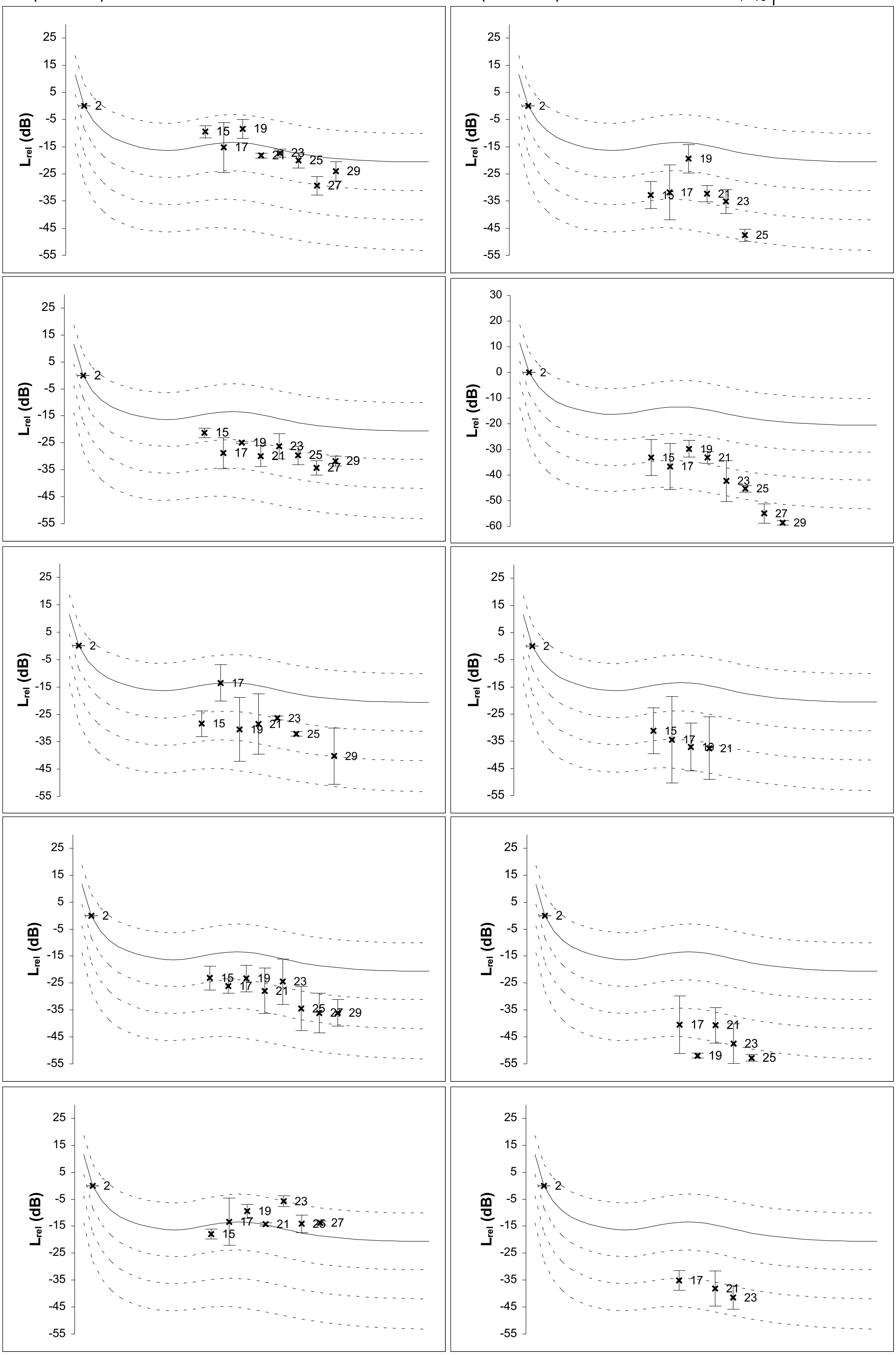
XI+

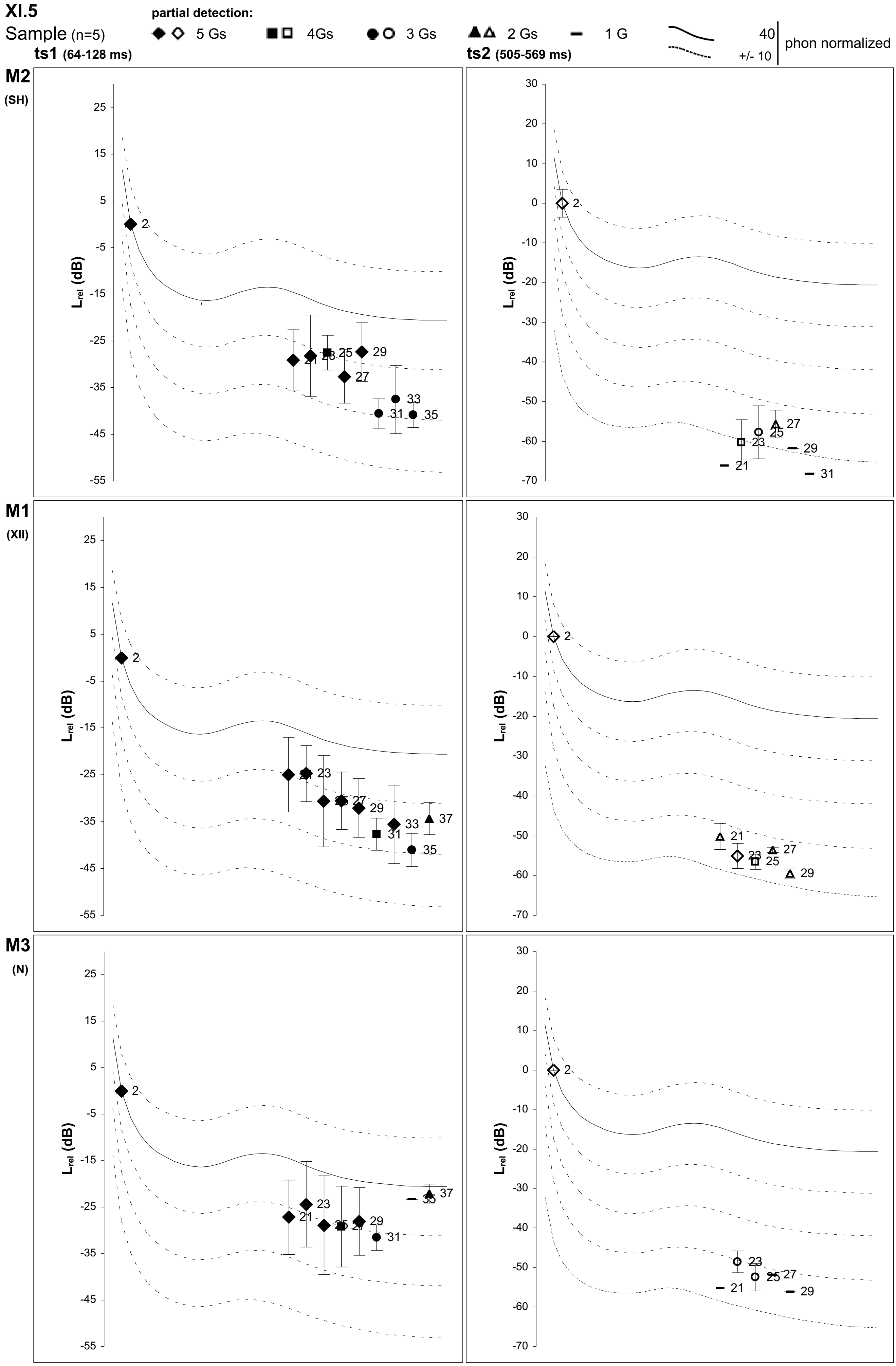
M3 **(Neck)**

ts1 **(64-128 ms)** | **ts2** **(505-569 ms)**

40 | phon normalized
+/- 10

G1
G2
G3
G4
G5

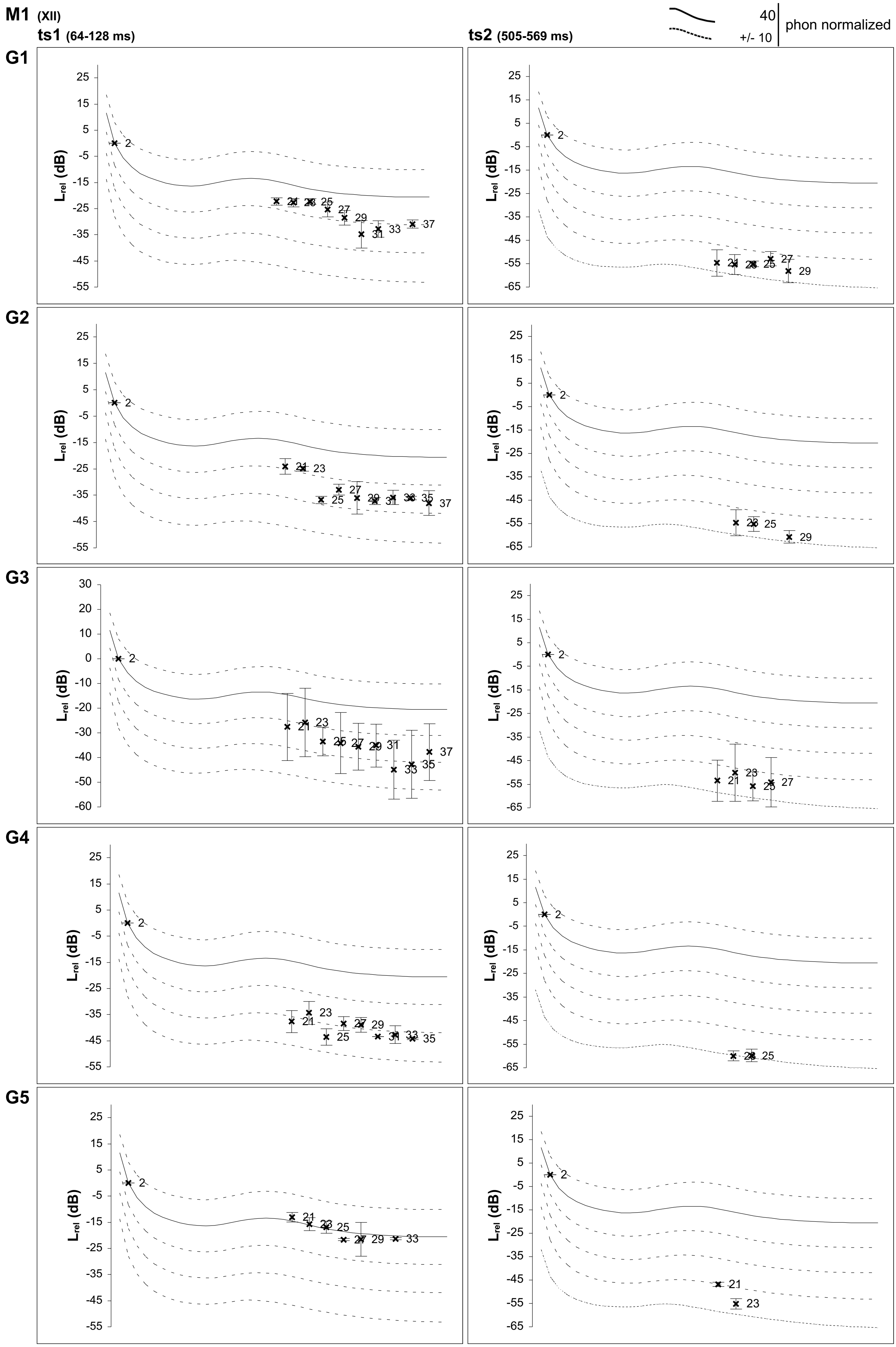




XI.5
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_{rel} (dB)

XI.5

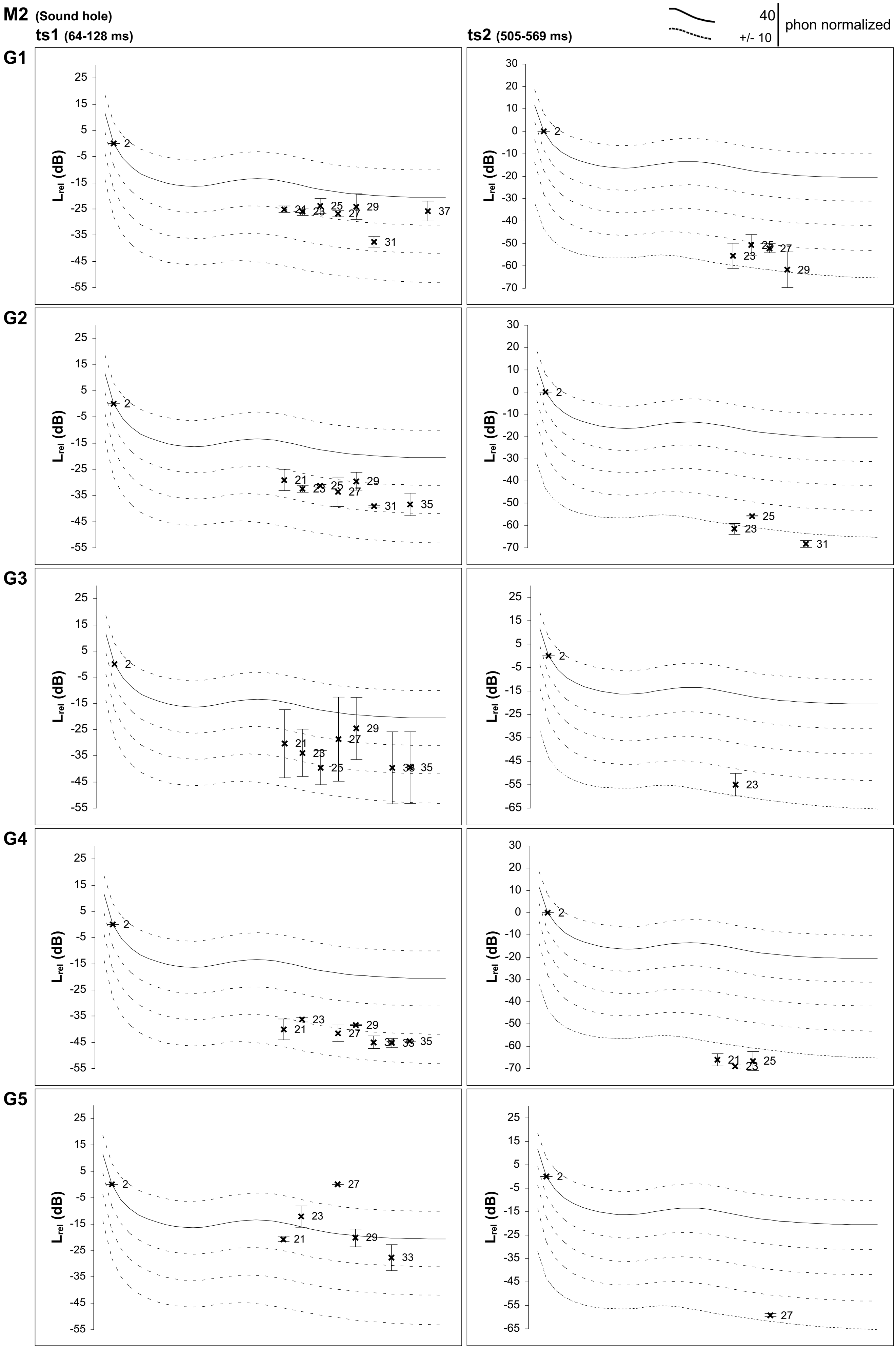
M1 (XII)



ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
L_rel (dB)

XI.5

M2 (Sound hole)



XI.5
M3 (Neck)

ts1 (64-128 ms) **ts2** (505-569 ms)

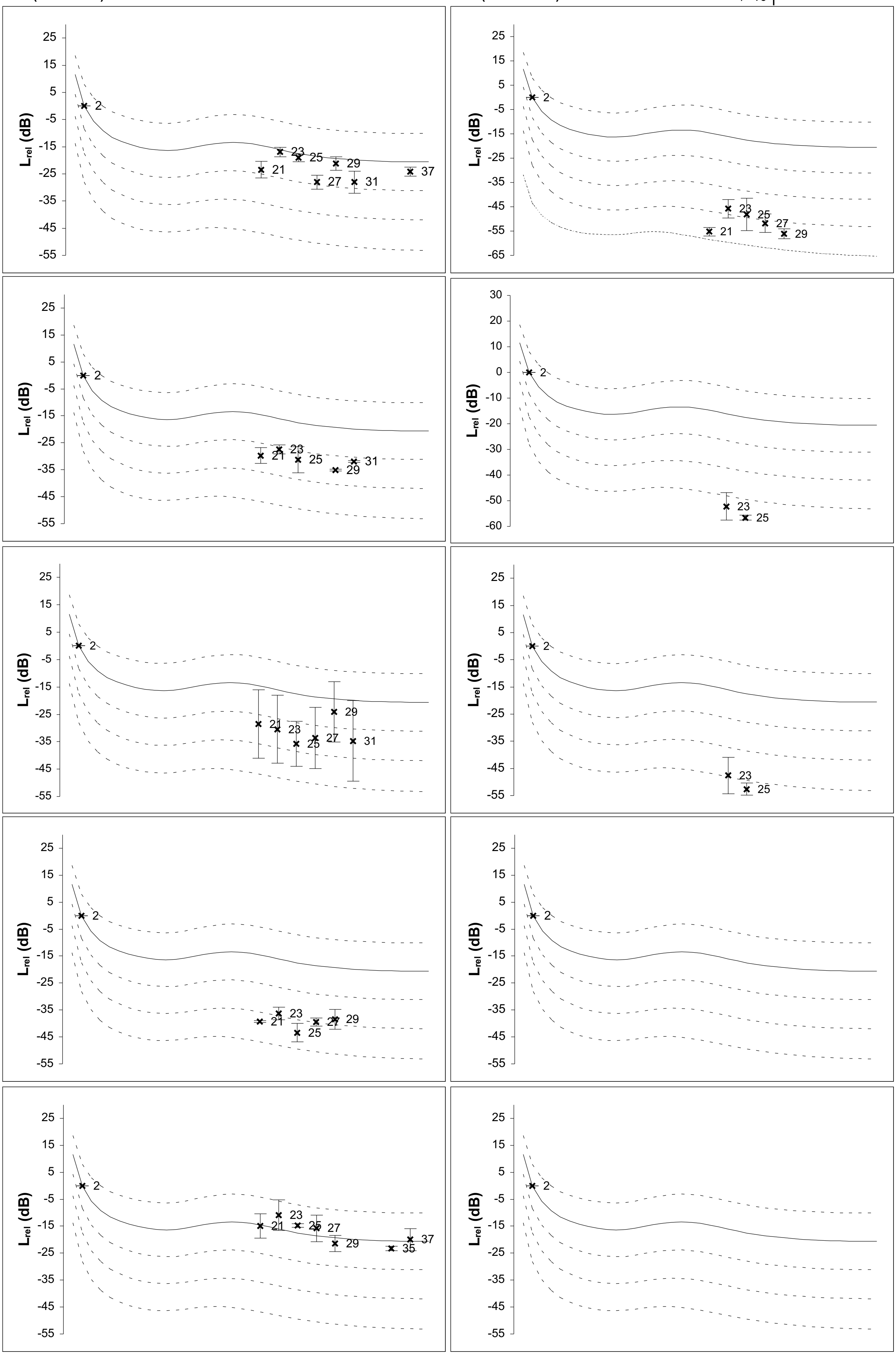
G1

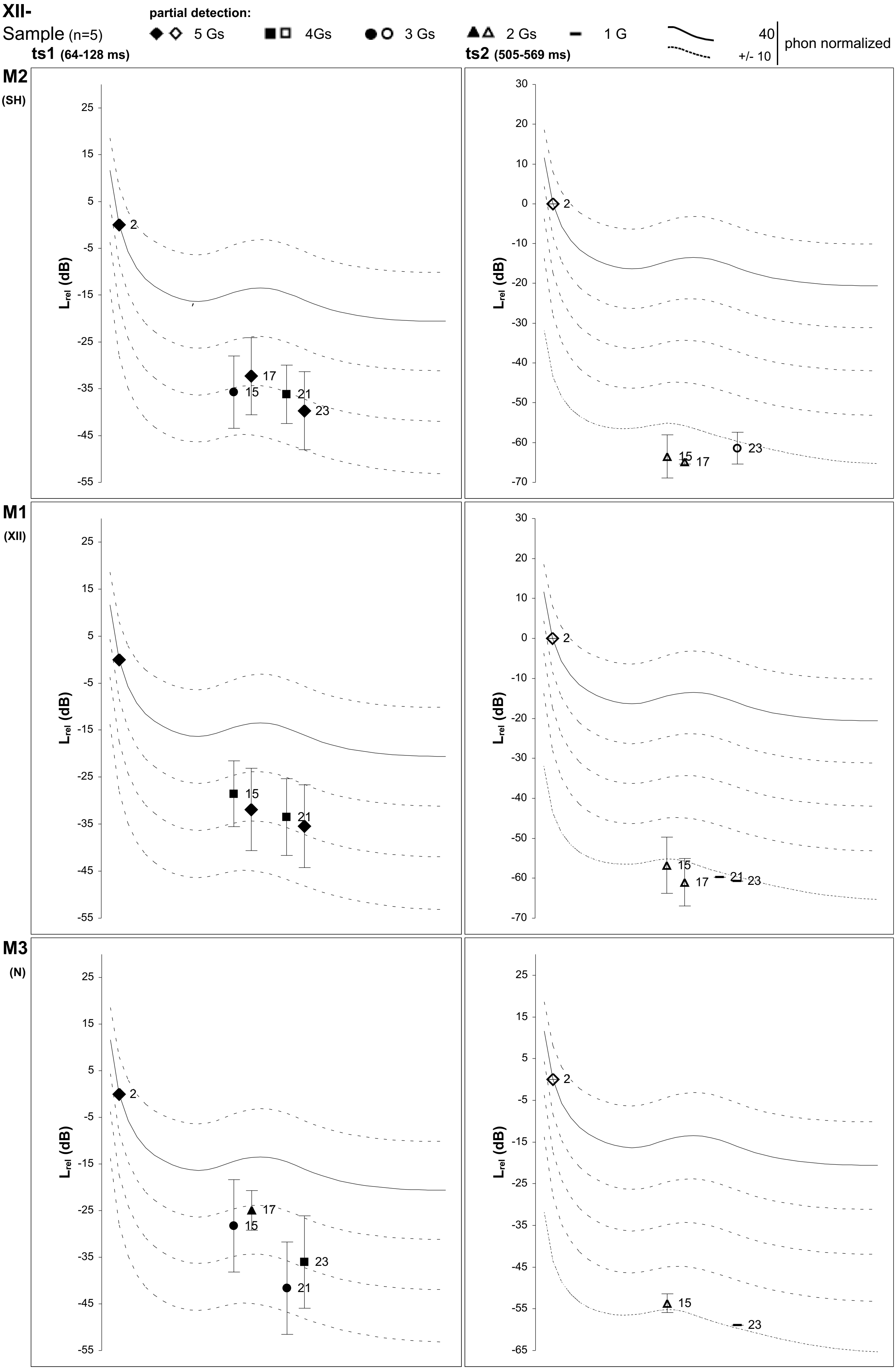
G2

G3

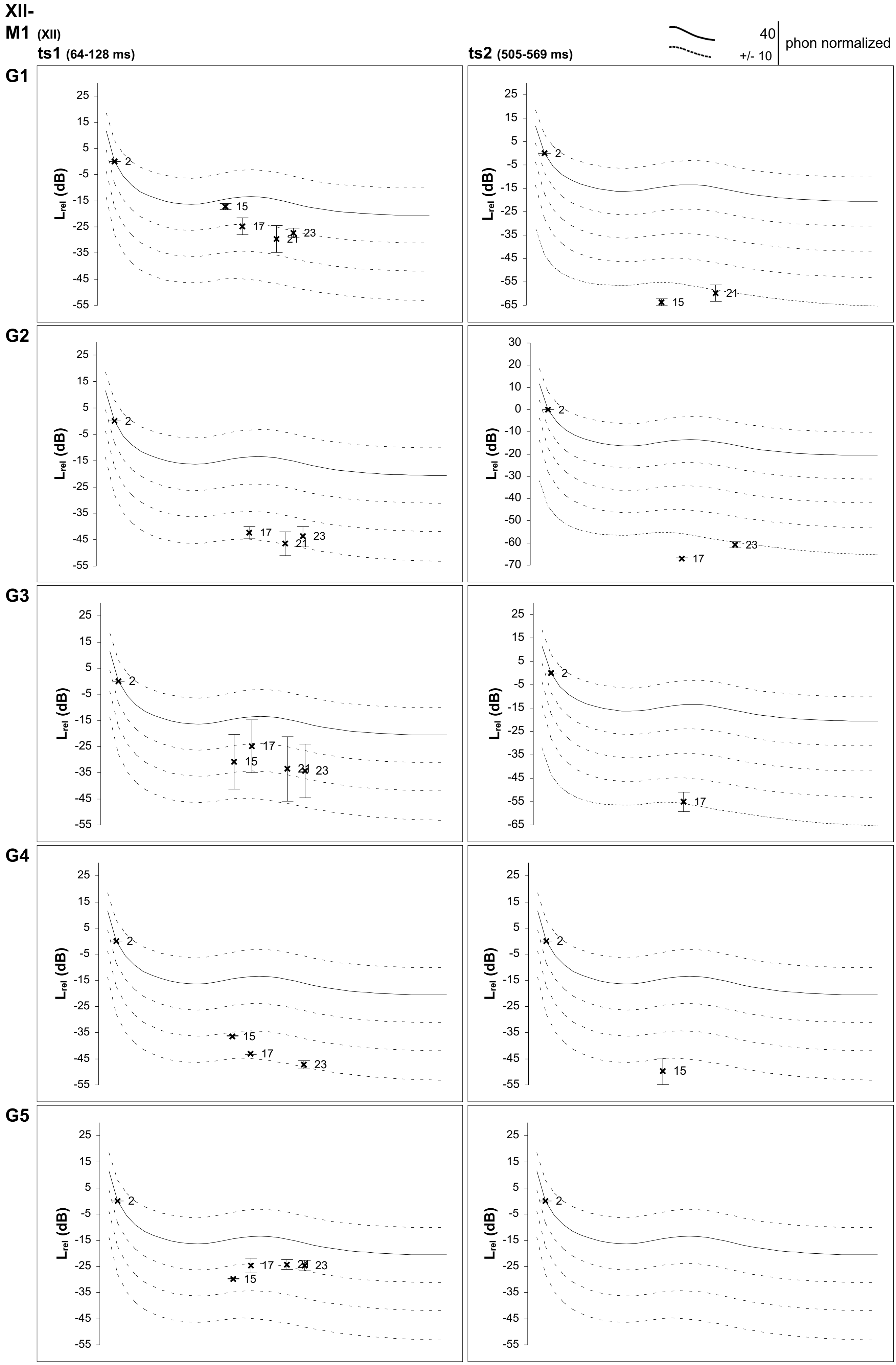
G4

G5

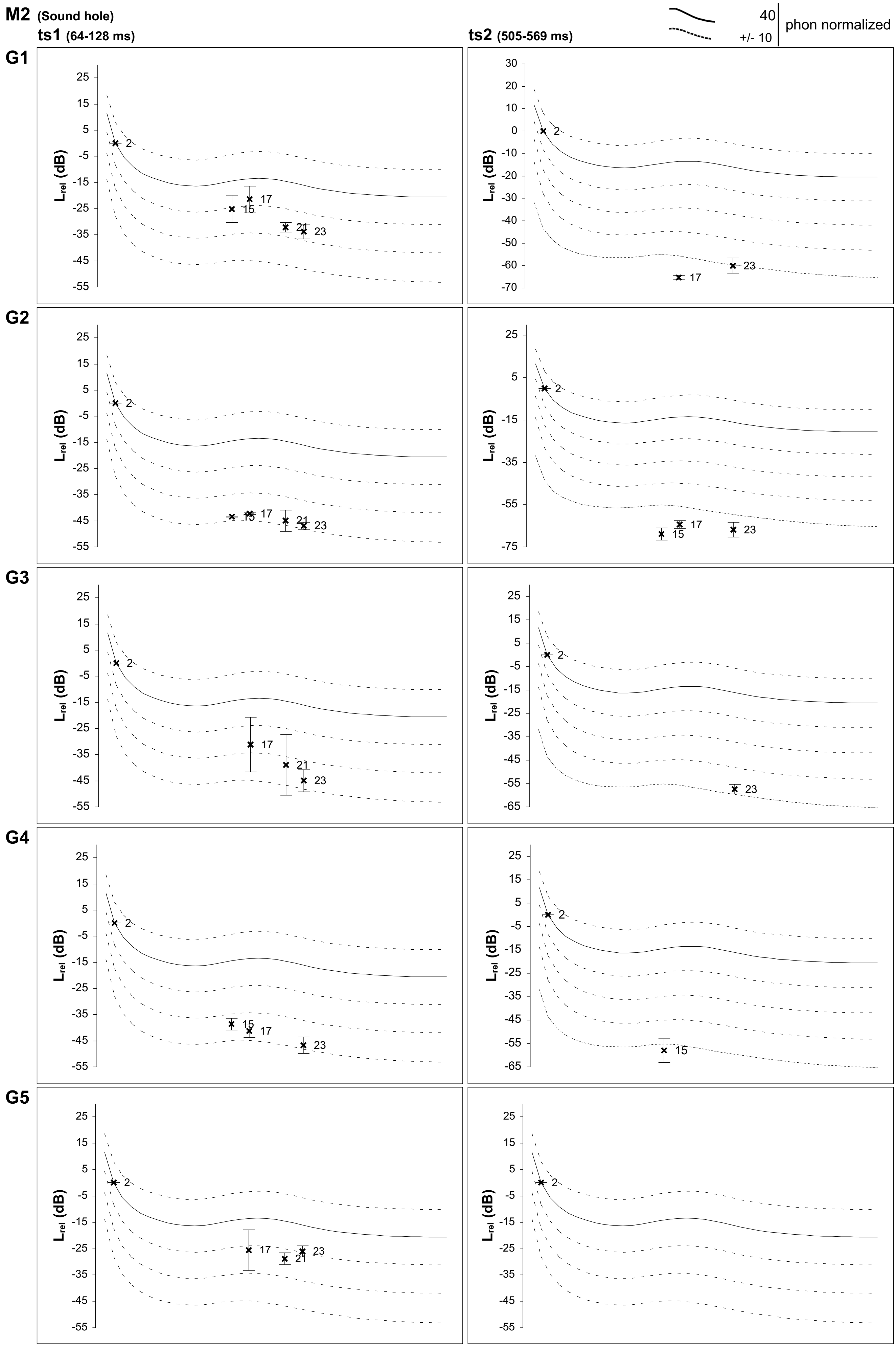




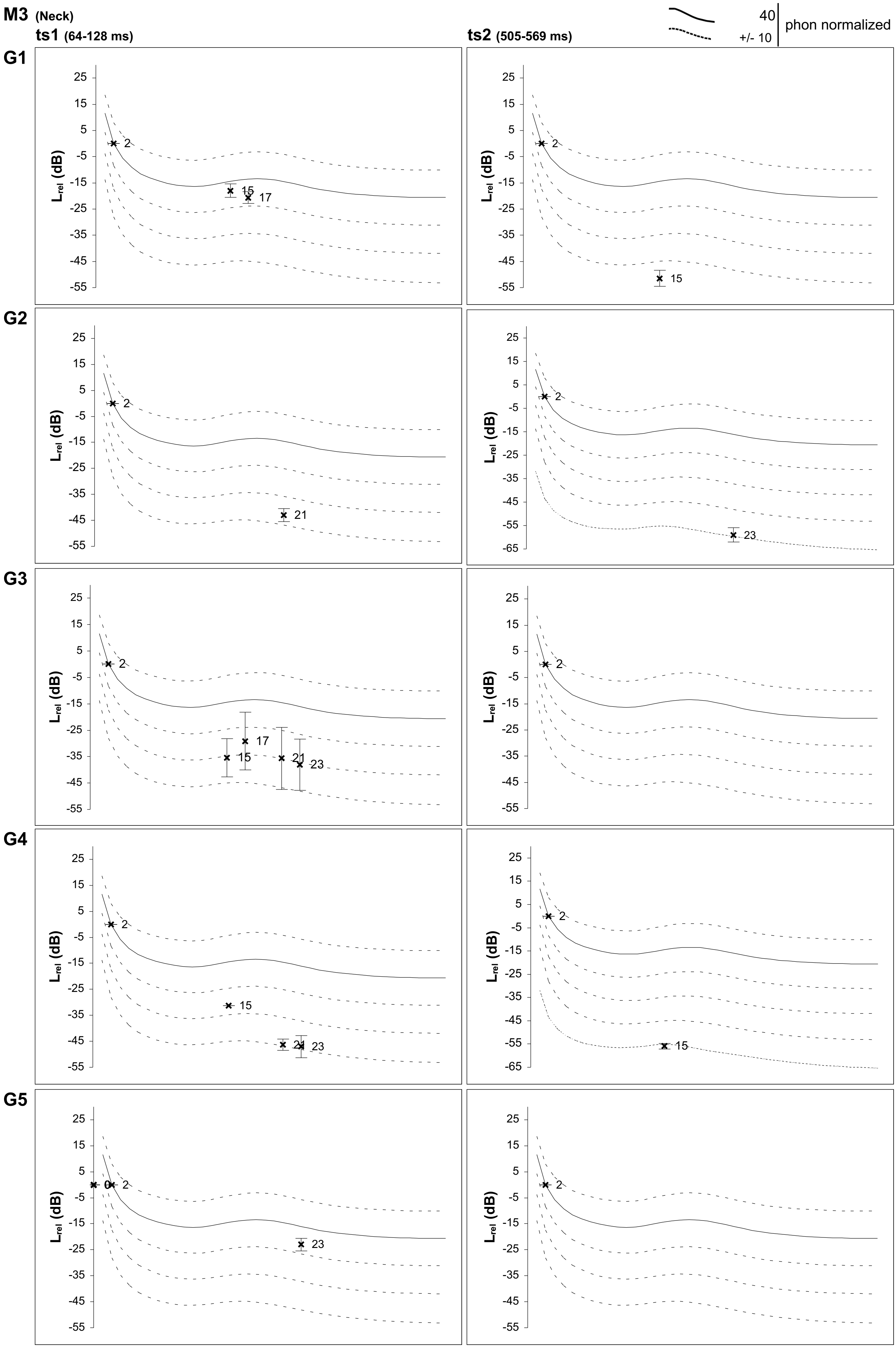
XII-
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
Lrel (dB)

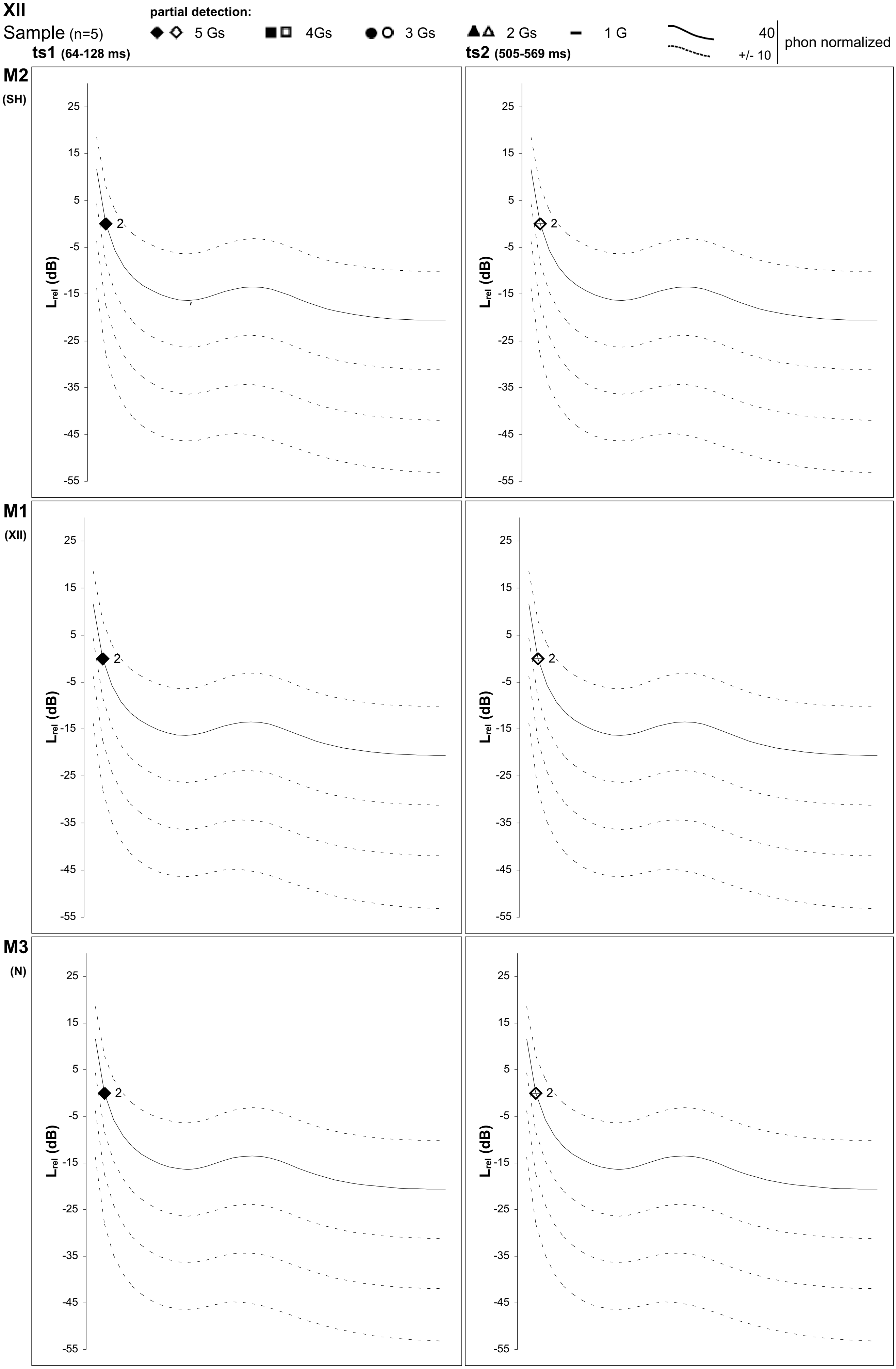

XII-
M1 (XII)
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
L_{rel} (dB)

XII-
M2 **(Sound hole)**



XII-
M3 (Neck)


40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
G1
G2
G3
G4
G5
Lrel (dB)
25
15
5
-5
-15
-25
-35
-45
-55
-65
2
15
17
21
23
0


XII
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_rel (dB)
25
15
5
-5
-15
-25
-35
-45
-55
2

XII

M1 **(XII)**

40 | phon normalized
+/- 10

ts1 **(64-128 ms)** **ts2** **(505-569 ms)**

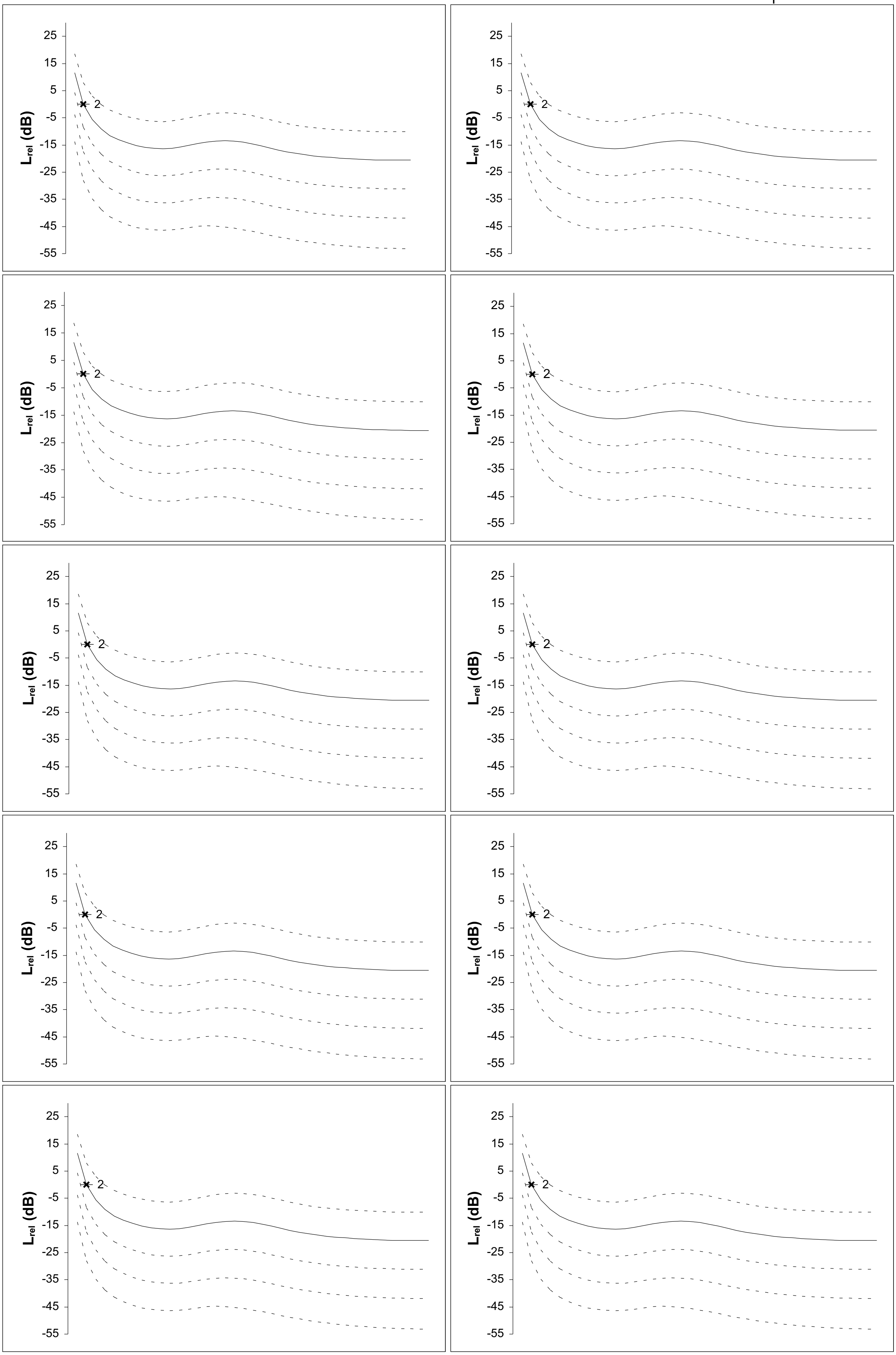
G1

G2

G3

G4

G5



XII

M2 **(Sound hole)**

40 phon normalized

+/- 10

ts1 **(64-128 ms)** **ts2** **(505-569 ms)**

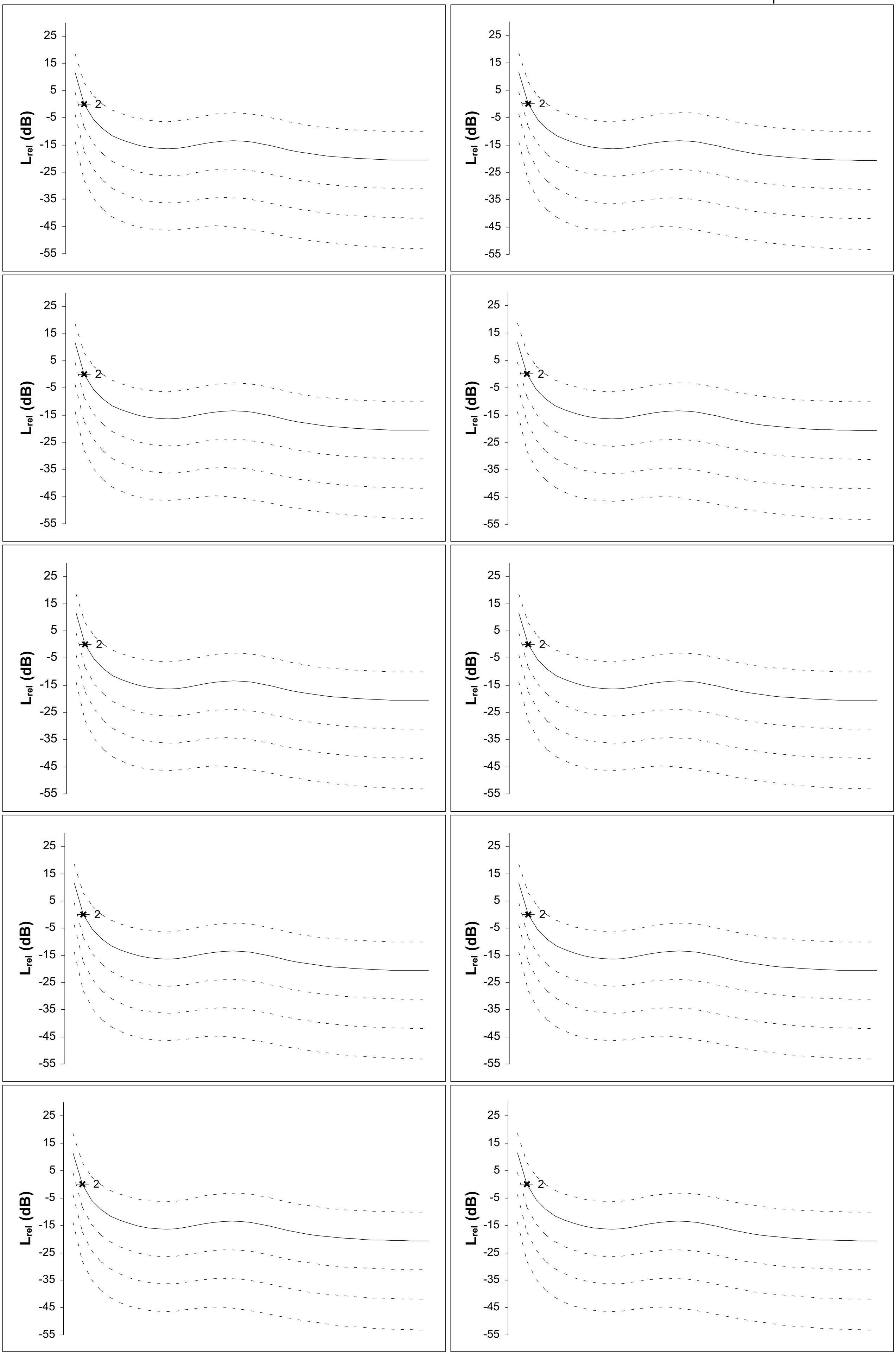
G1

G2

G3

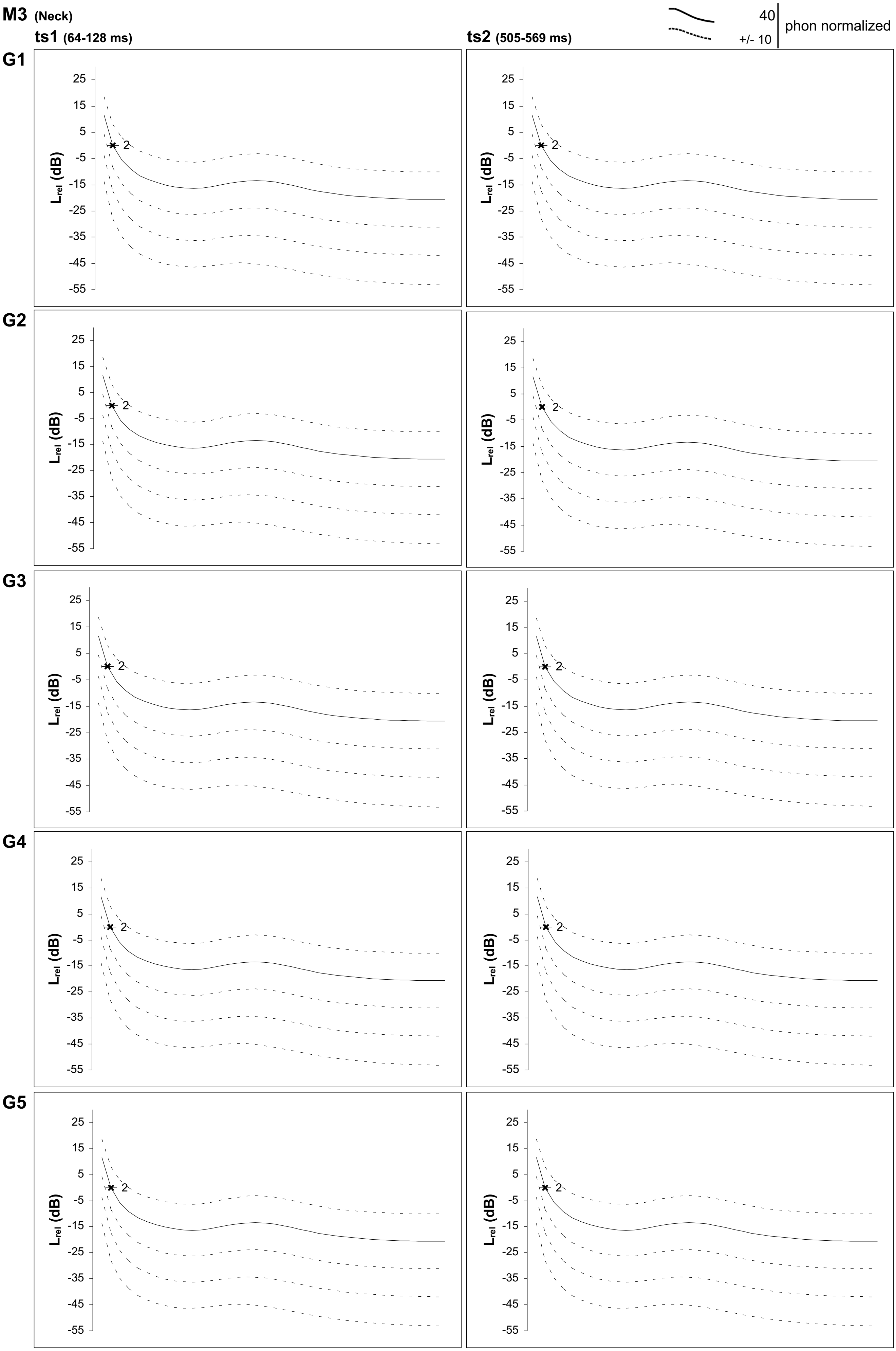
G4

G5

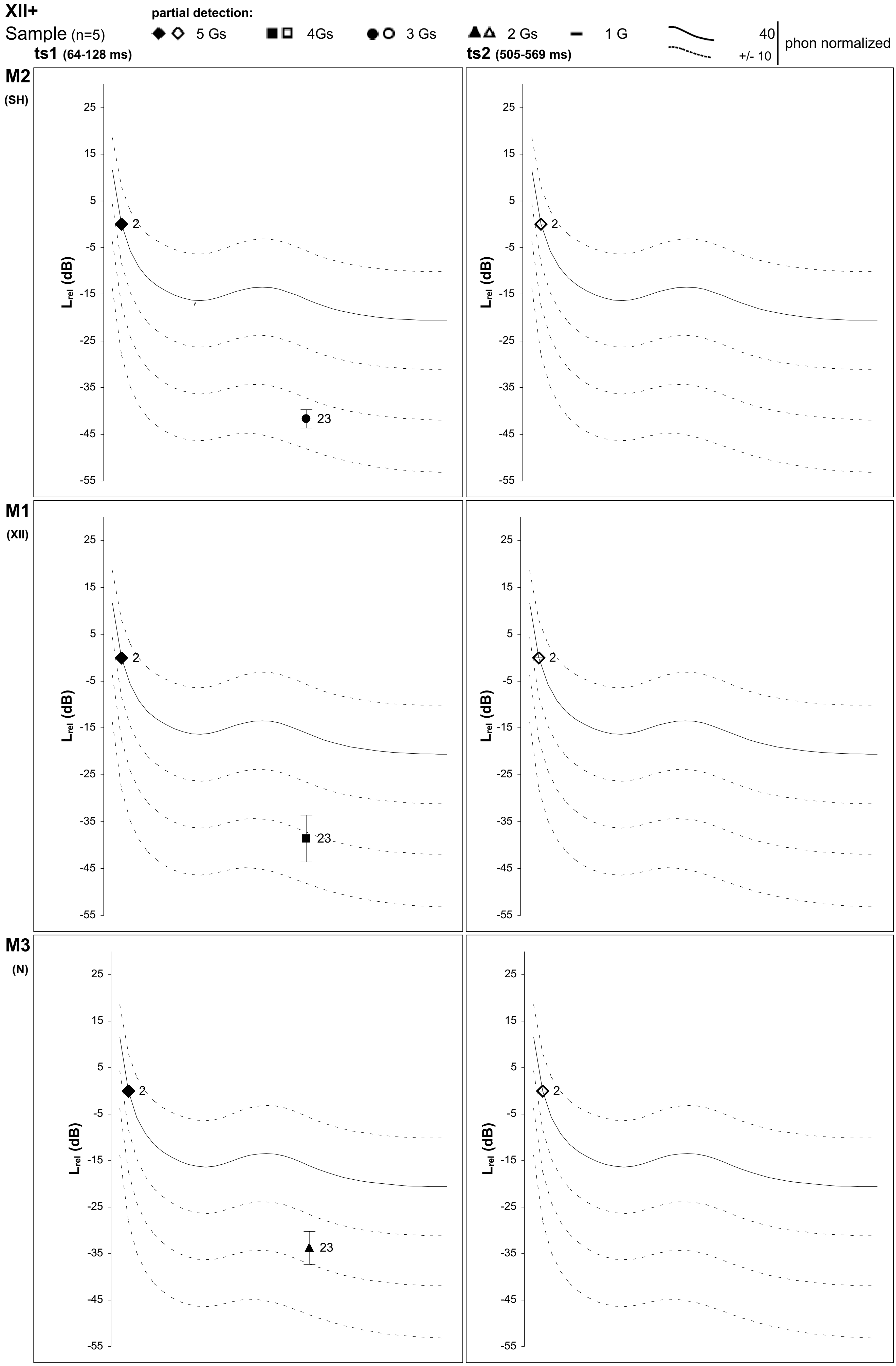


XII

M3 **(Neck)**



40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
G1
G2
G3
G4
G5
25
15
5
-5
-15
-25
-35
-45
-55
L_{rel} (dB)
2


XII+
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_rel (dB)
25
15
5
-5
-15
-25
-35
-45
-55
2
23

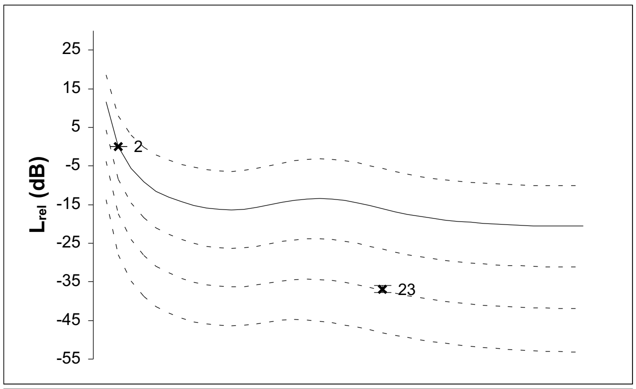
XII+

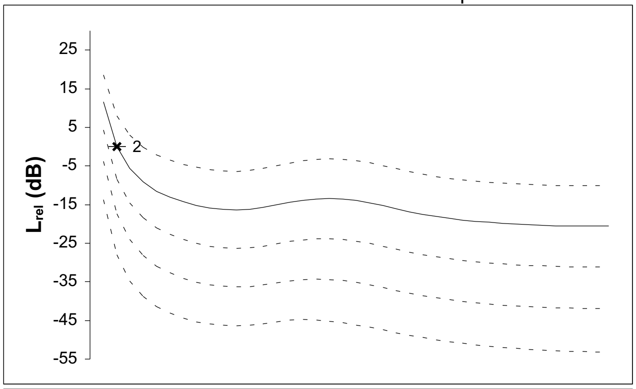
M1 (XII)

ts1 (64-128 ms) **ts2** (505-569 ms)

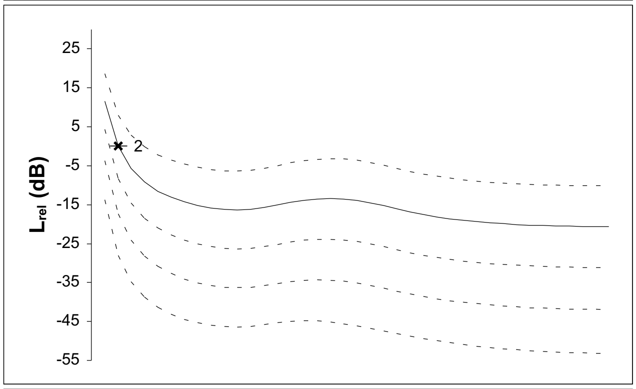
40 / +/- 10 phon normalized

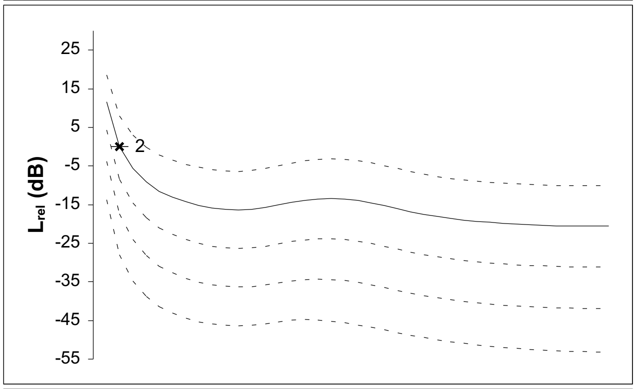
G1



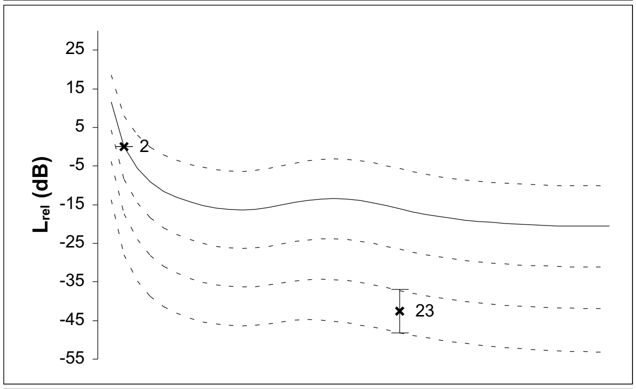


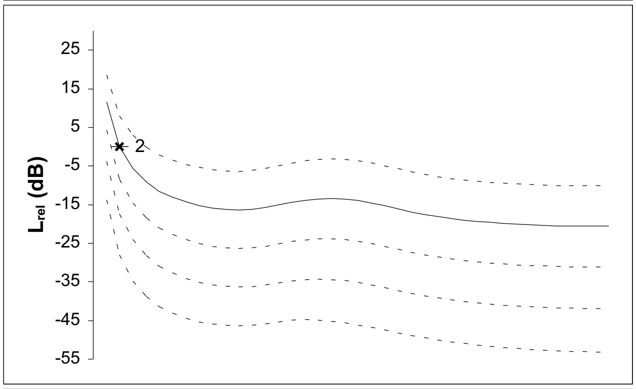
G2



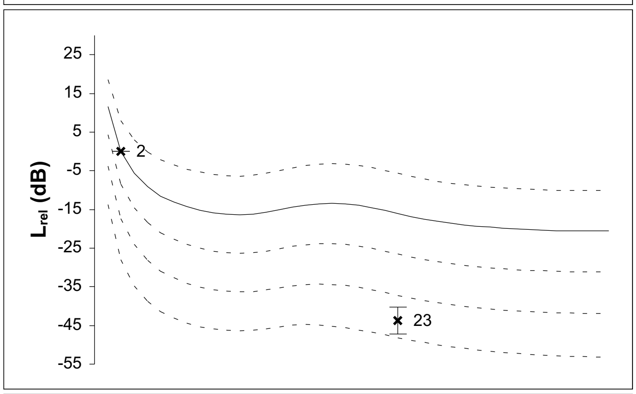


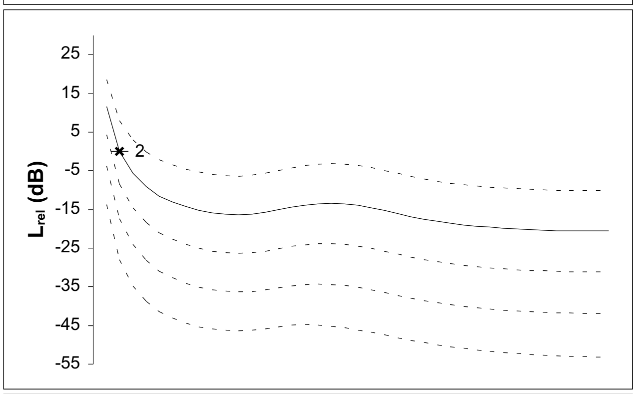
G3



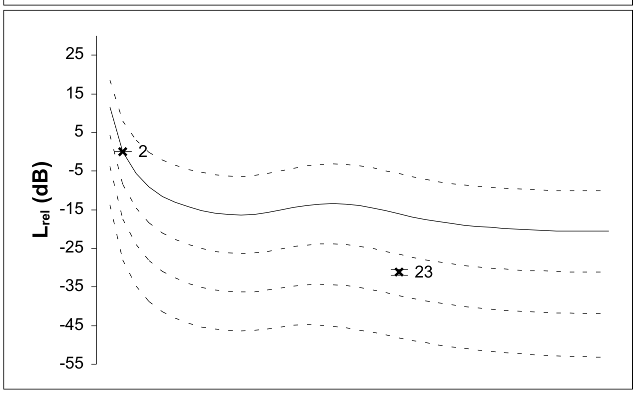


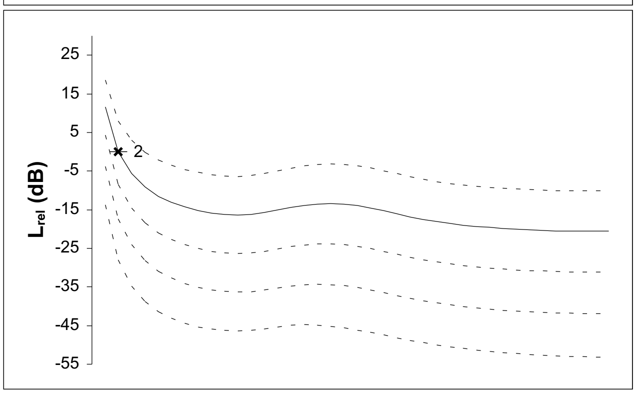
G4





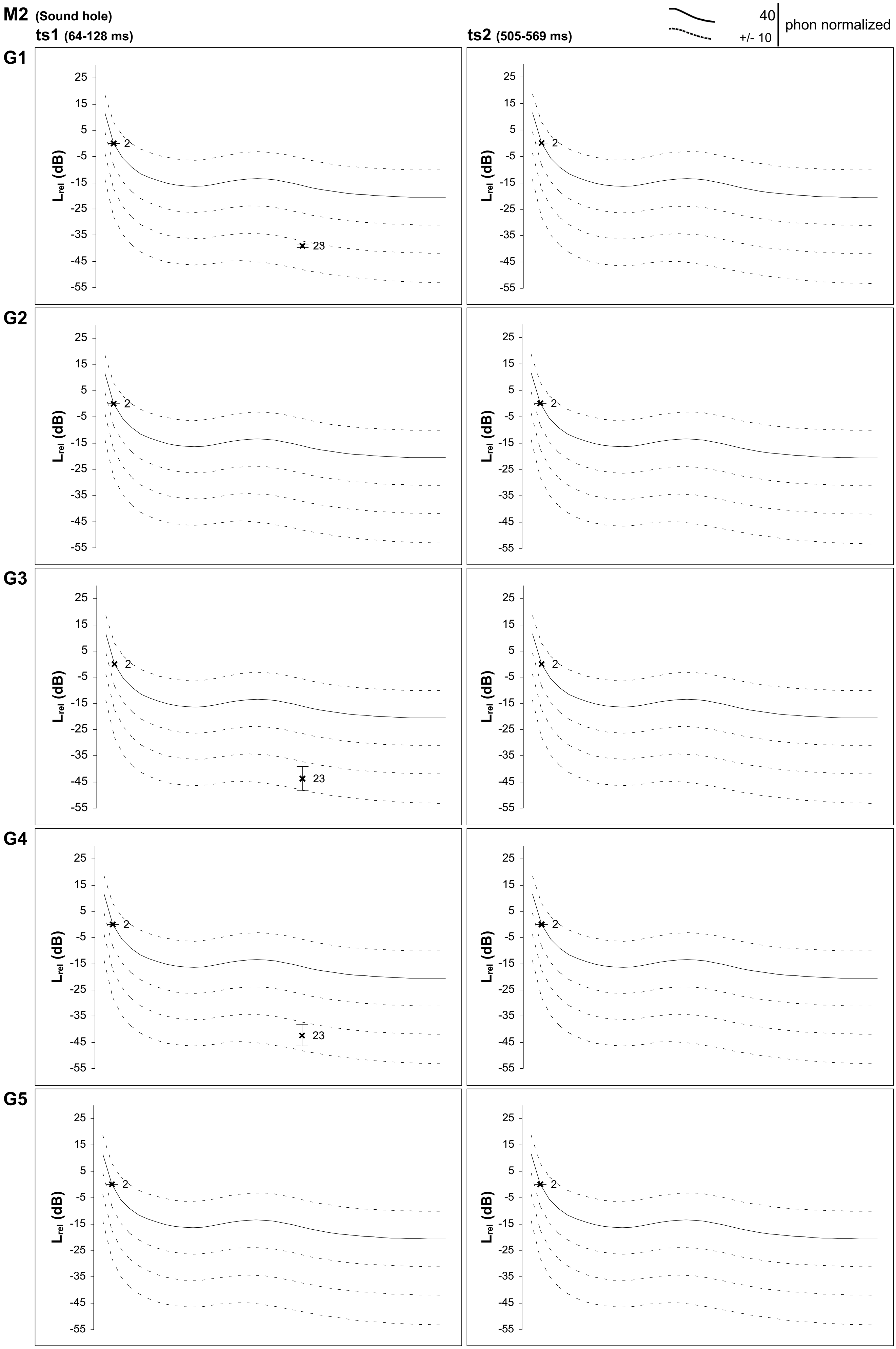
G5





XII+

M2 (Sound hole)



XII+

M3 (Neck)

ts1 (64-128 ms) **ts2** (505-569 ms)

40 / +/- 10 phon normalized

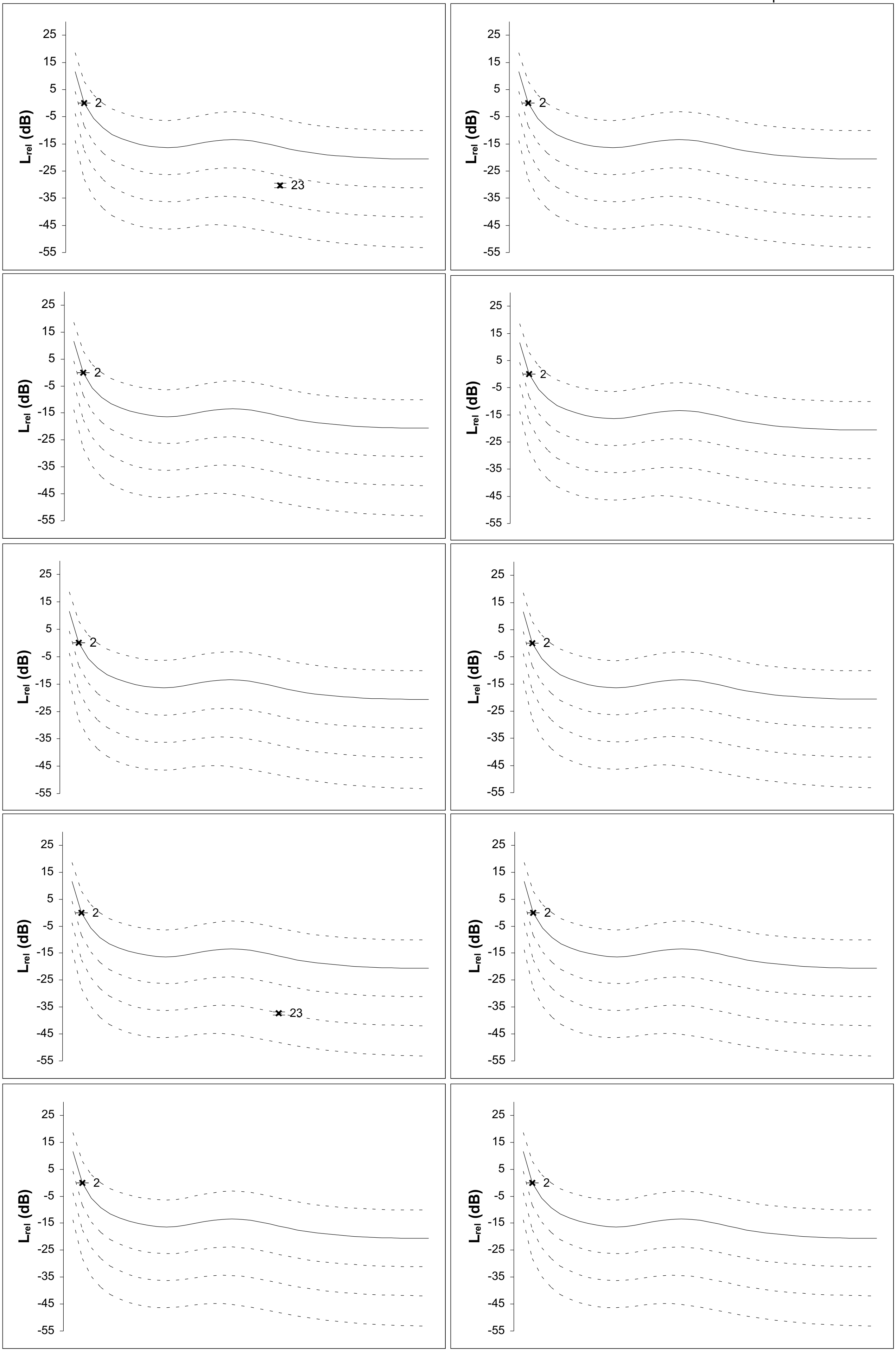
G1

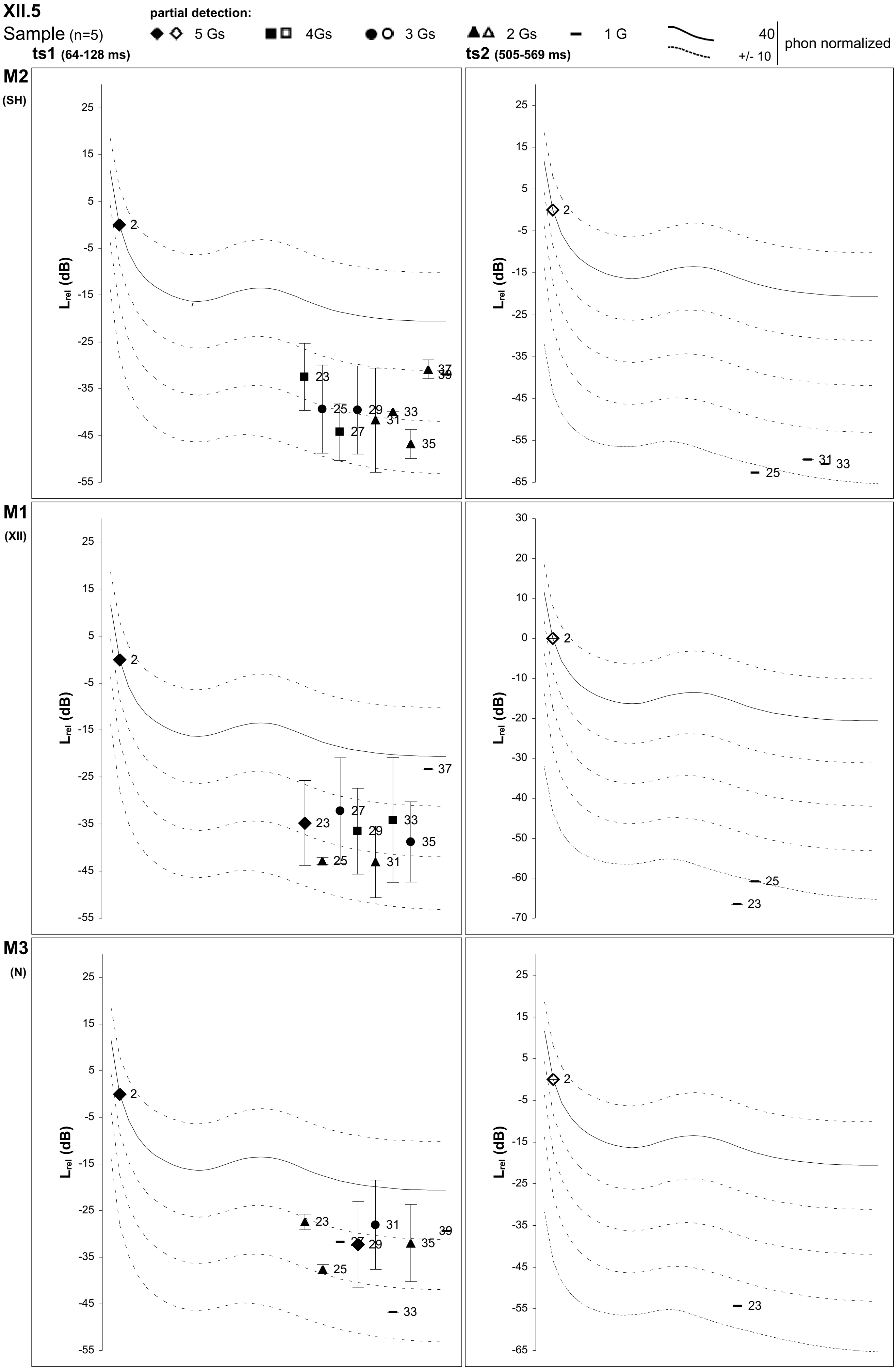
G2

G3

G4

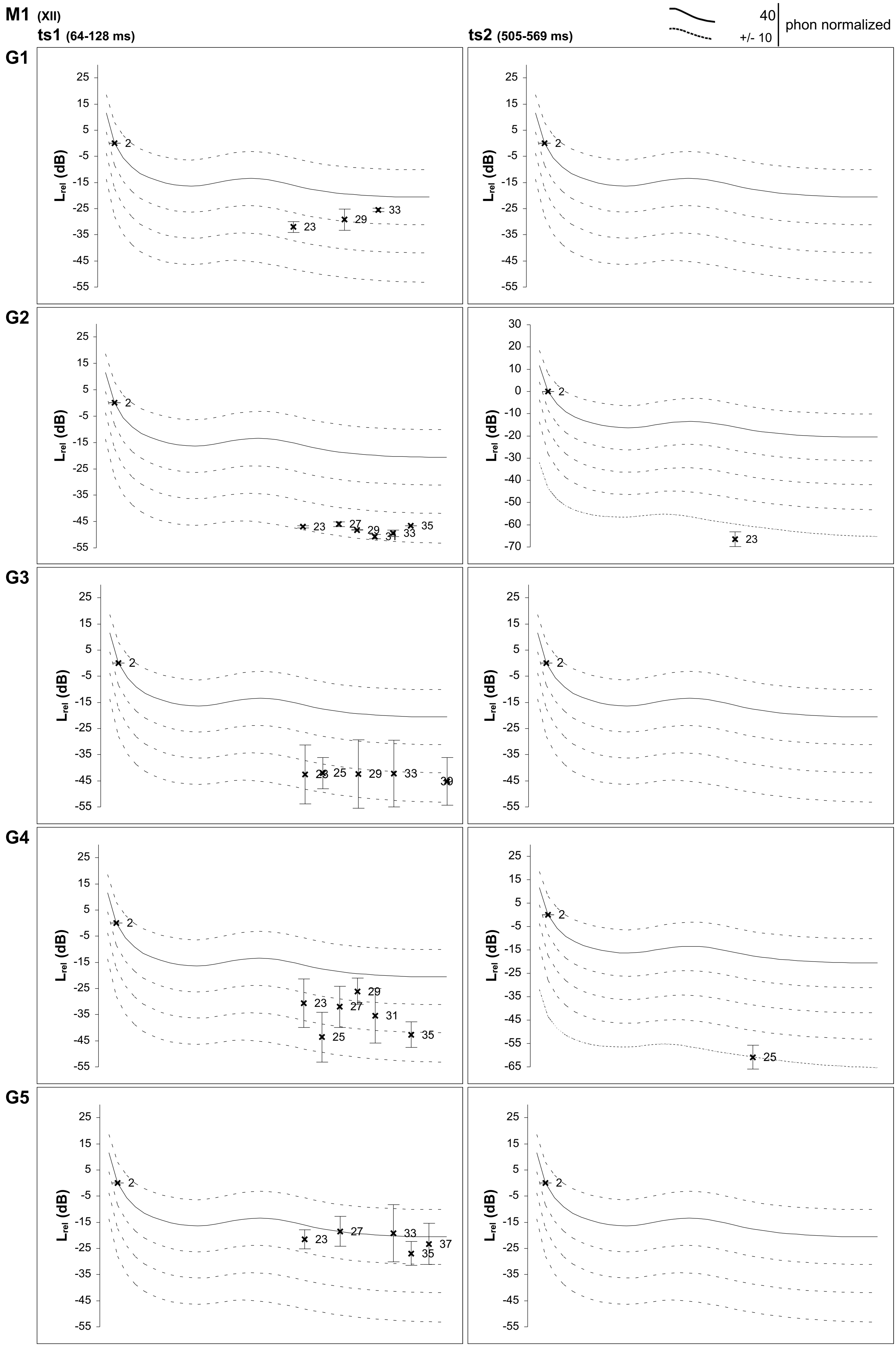
G5



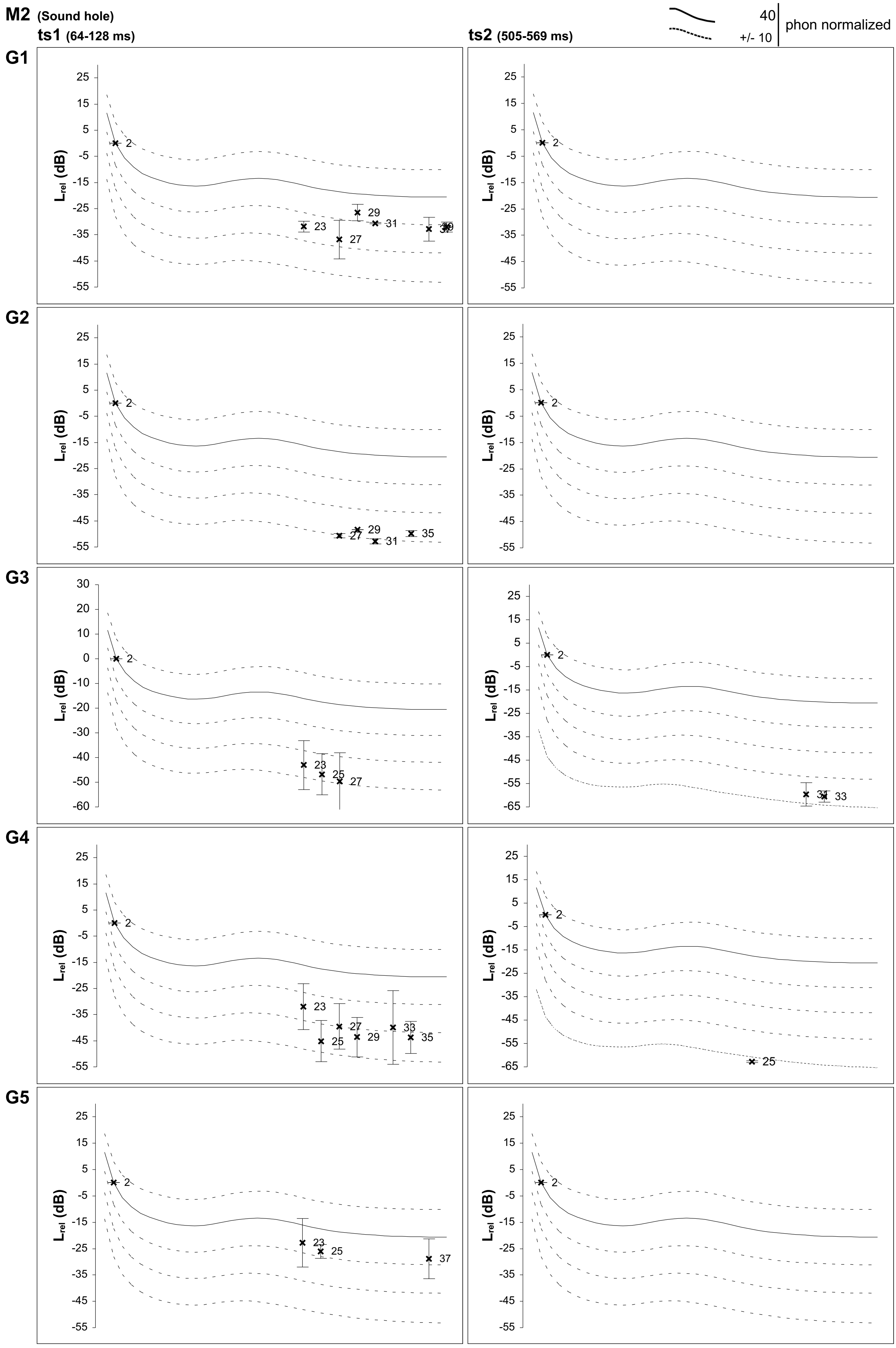

XII.5
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_rel (dB)

XII.5

M1 (XII)

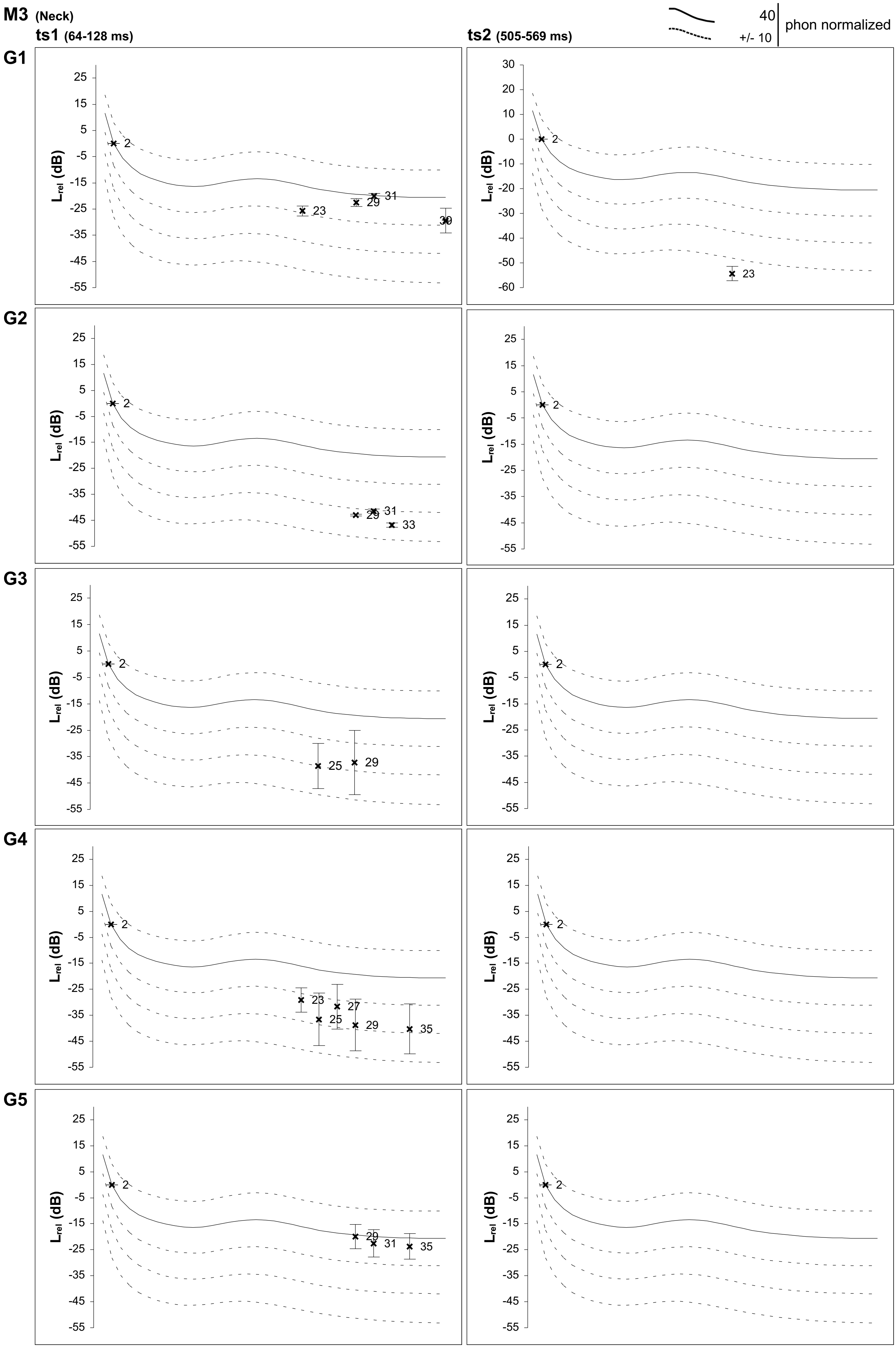

ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
L_{rel} (dB)

XII.5


M2 (Sound hole)
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
Lrel (dB)

XII.5

M3 (Neck)

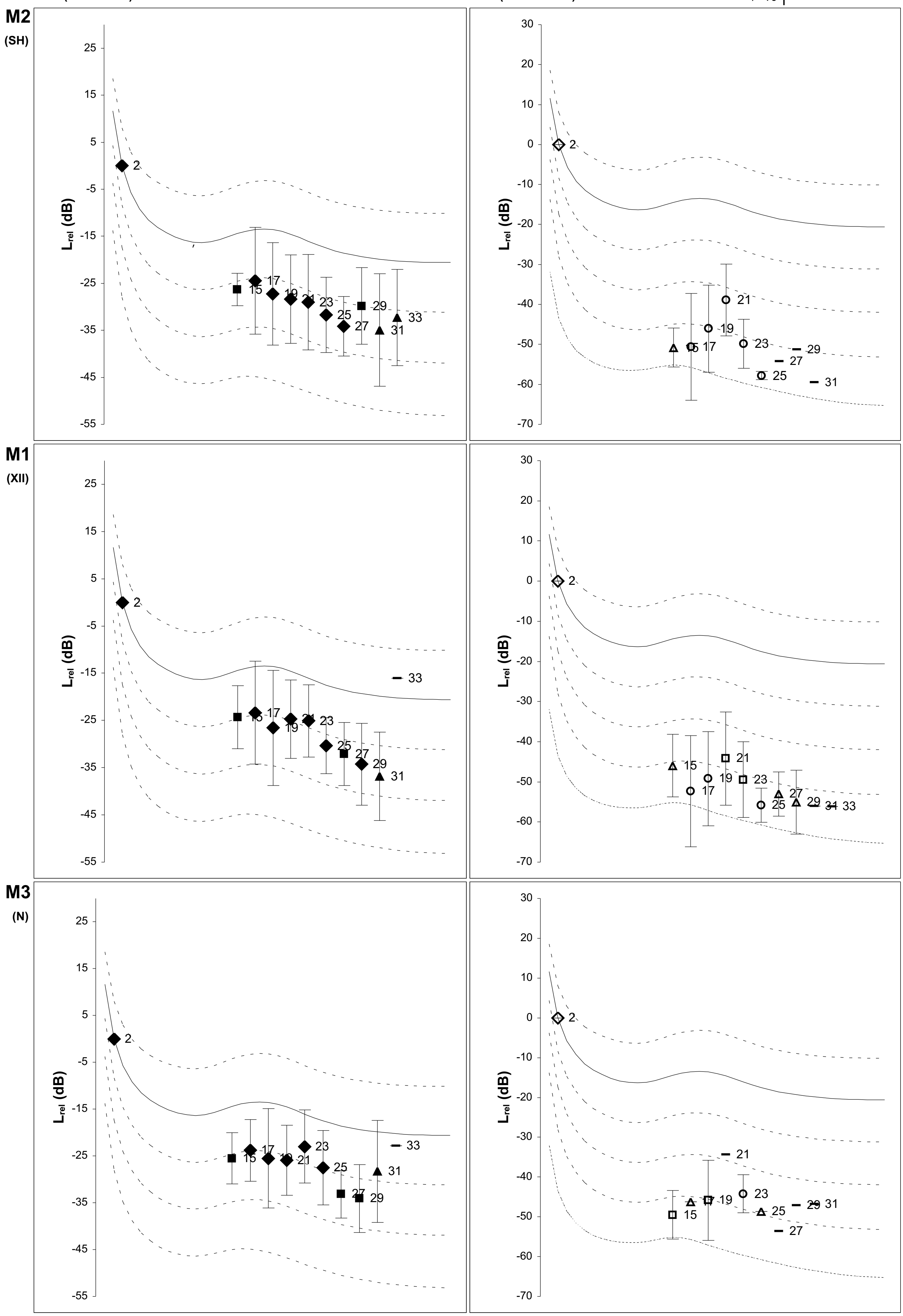


ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
L_rel (dB)

XIII-
Sample (n=5)

partial detection: 5 Gs | 4Gs | 3 Gs | 2 Gs | 1 G | 40 / +/- 10 phon normalized

ts1 (64-128 ms) | **ts2** (505-569 ms)

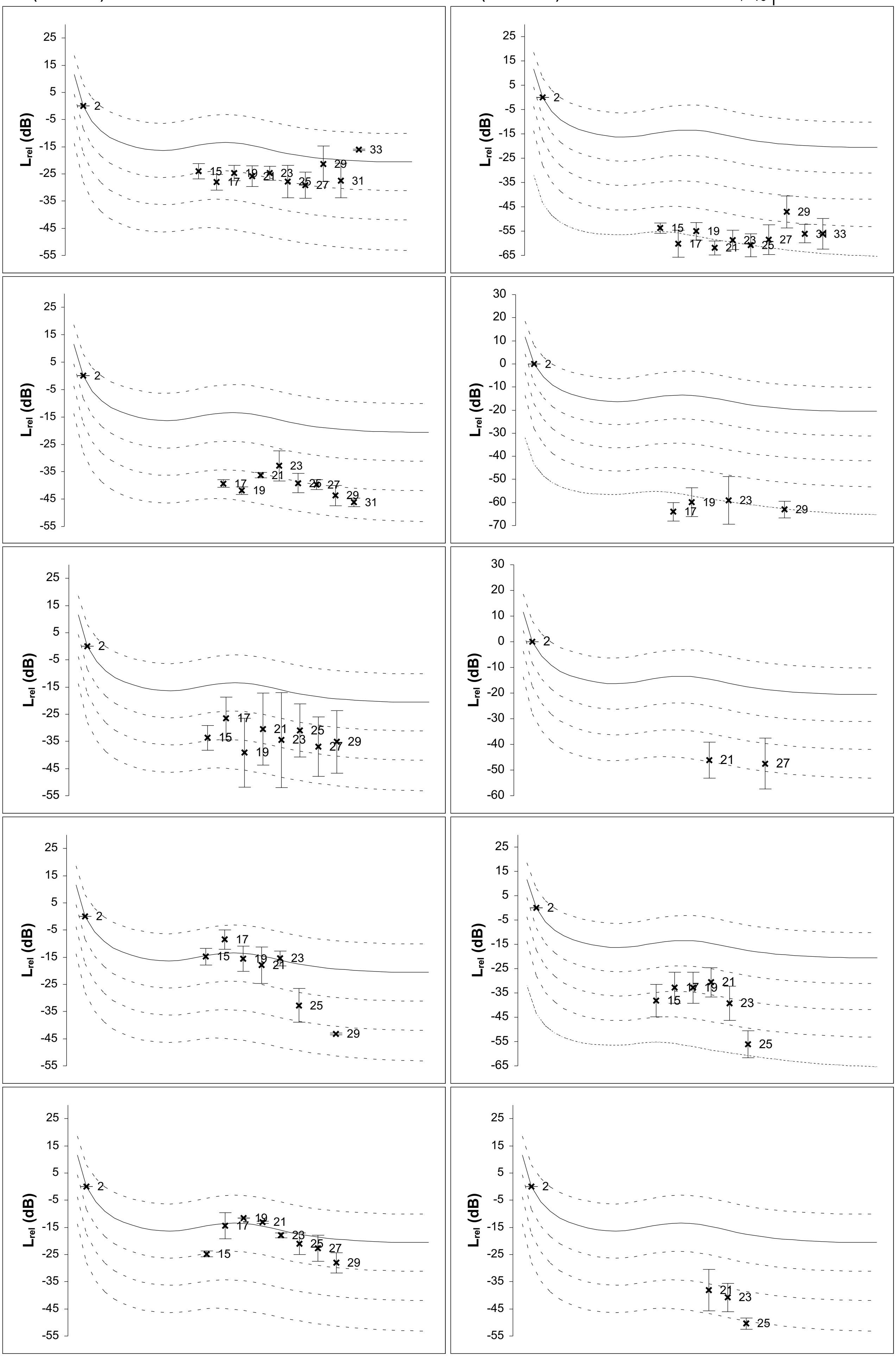


XIII-
M1 **(XII)**

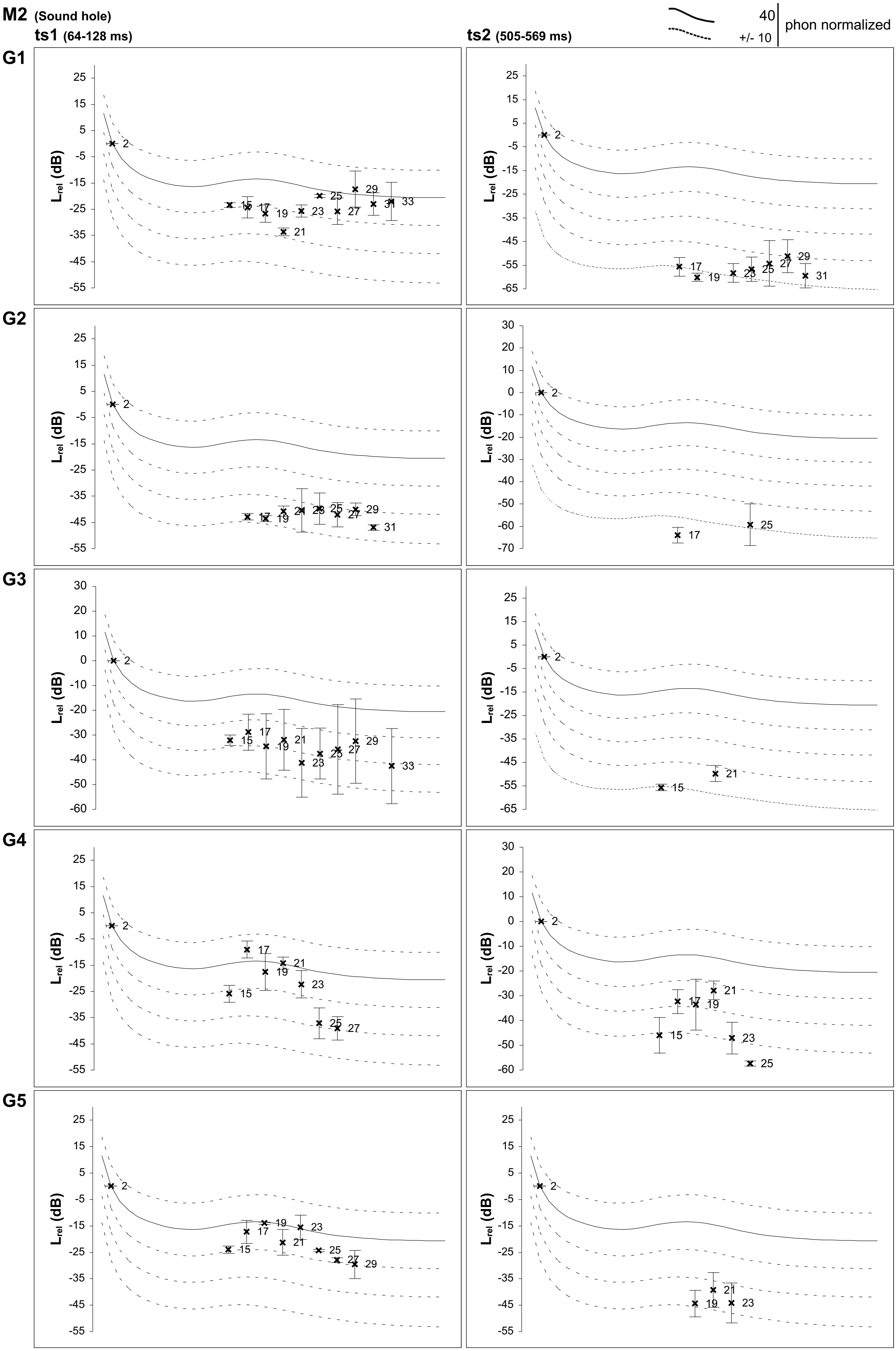
40 | +/- 10 — phon normalized

ts1 **(64-128 ms)** **ts2** **(505-569 ms)**

G1
G2
G3
G4
G5

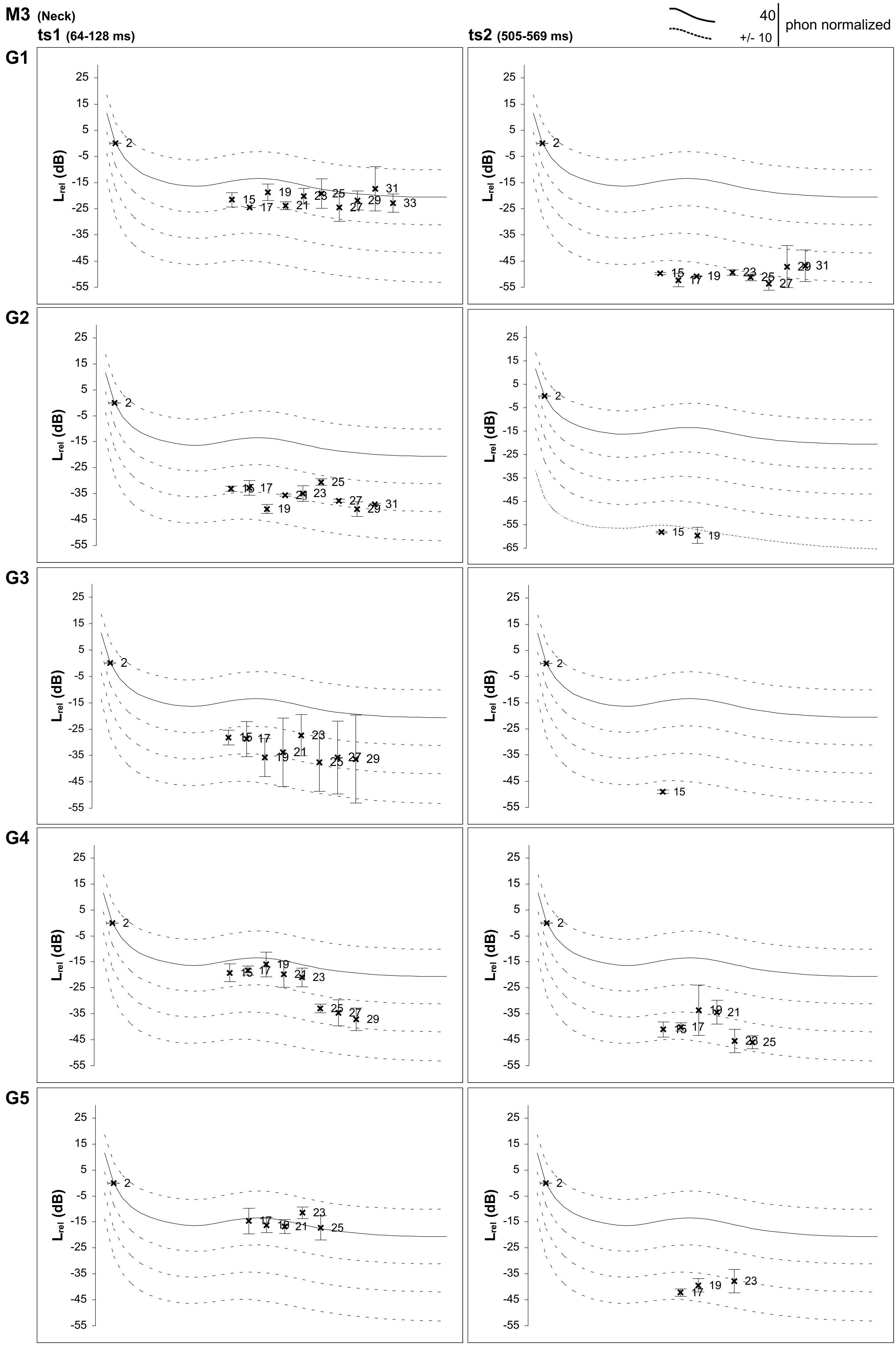


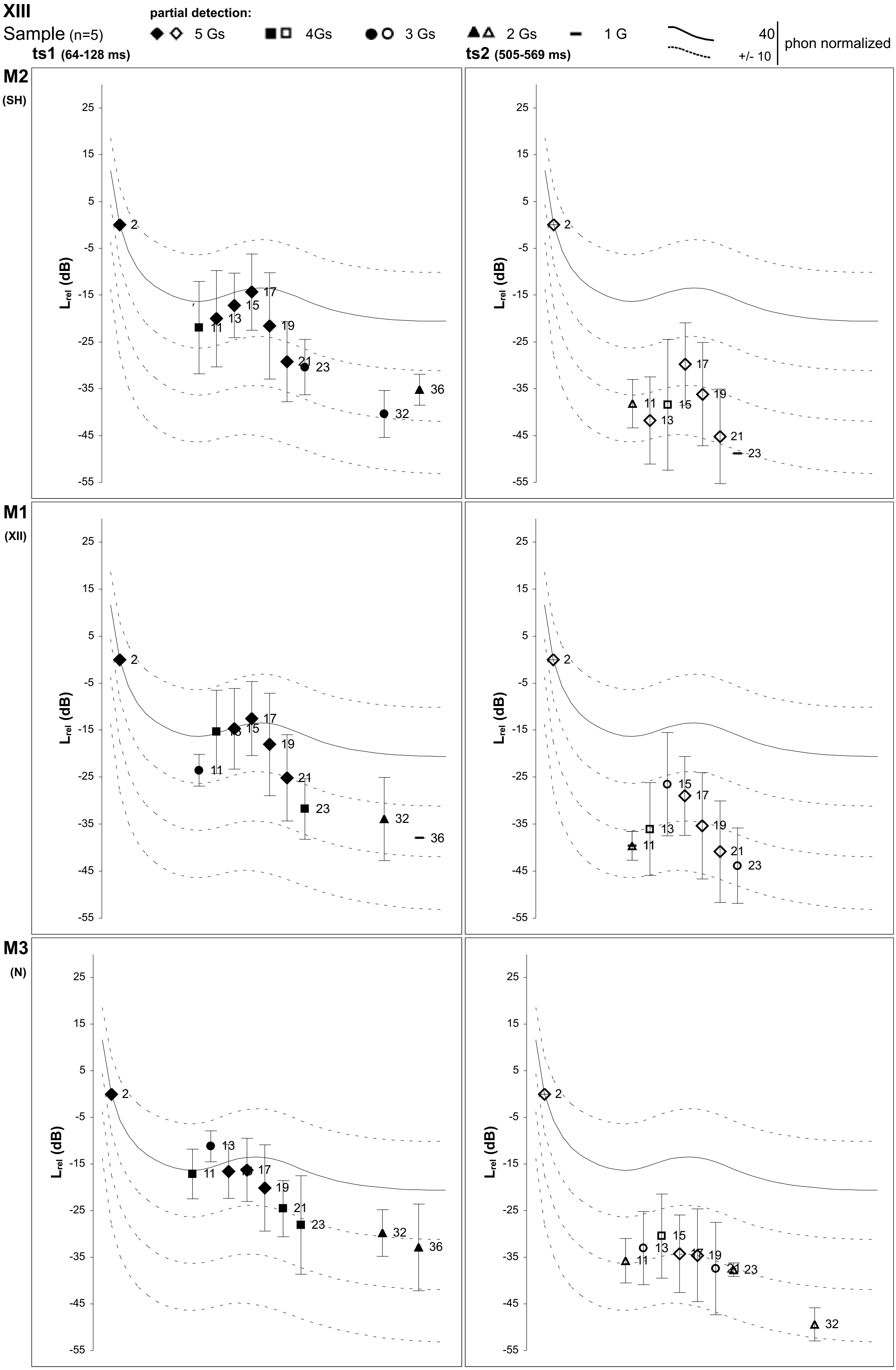
XIII-
M2 (Sound hole)



XIII-

M3 (Neck)


40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
G1
G2
G3
G4
G5
L_rel (dB)
25
15
5
-5
-15
-25
-35
-45
-55
-65


XIII
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
Lrel (dB)

XIII

M1 (XII)

40 / +/- 10 — phon normalized

ts1 (64-128 ms) **ts2** (505-569 ms)

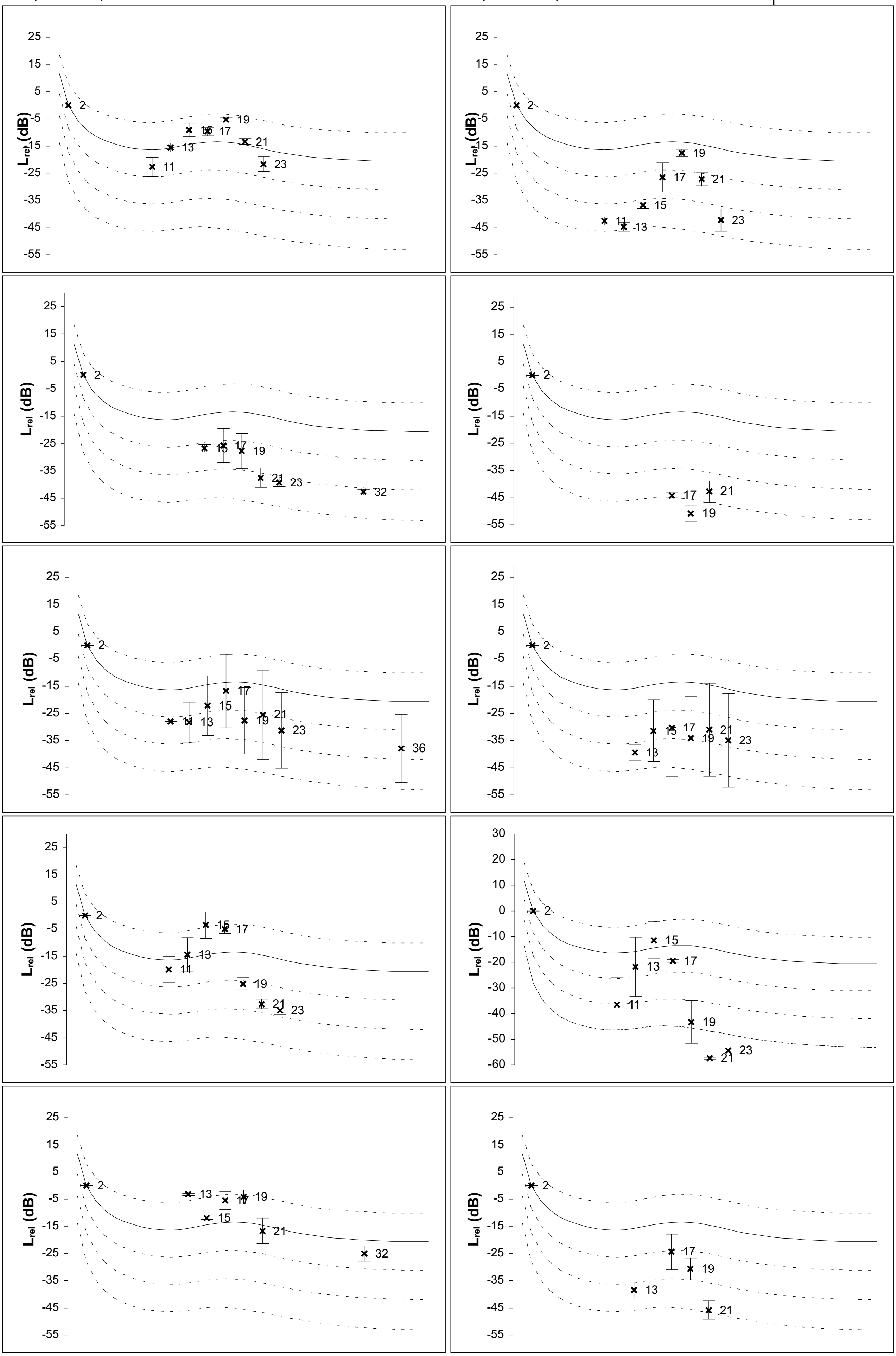
G1

G2

G3

G4

G5

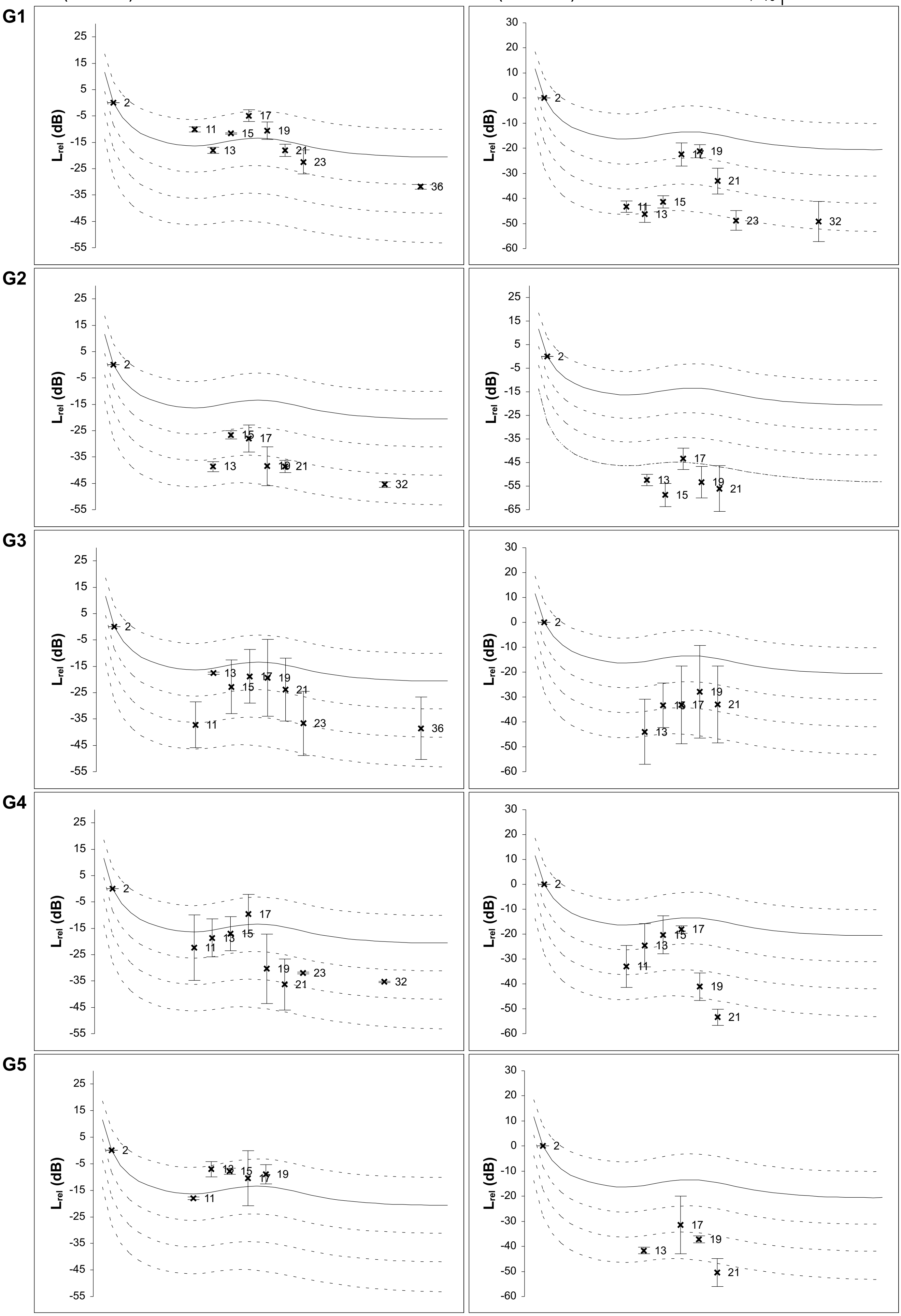


XIII

M2 (Sound hole)

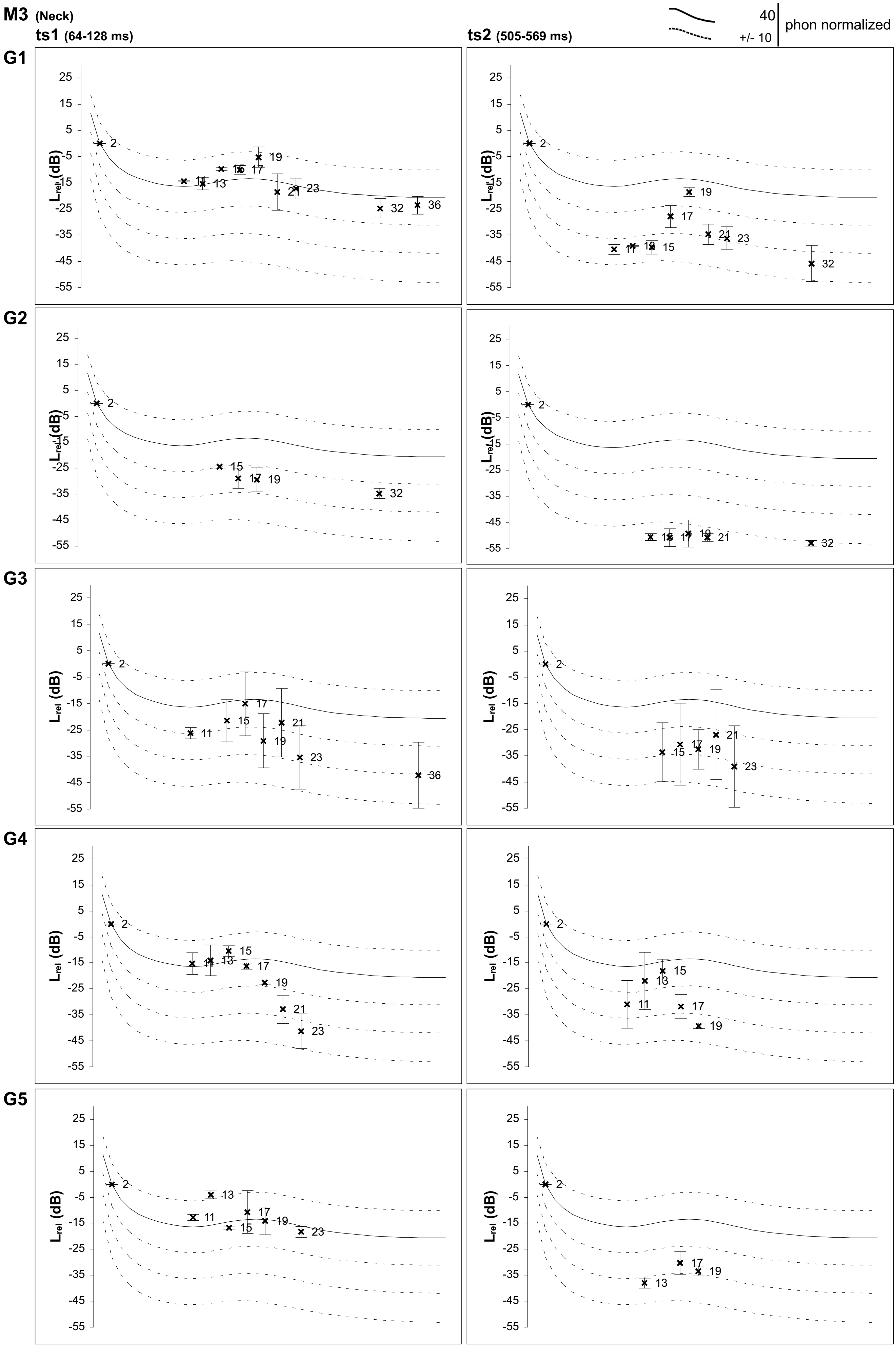
40 | phon normalized
+/- 10

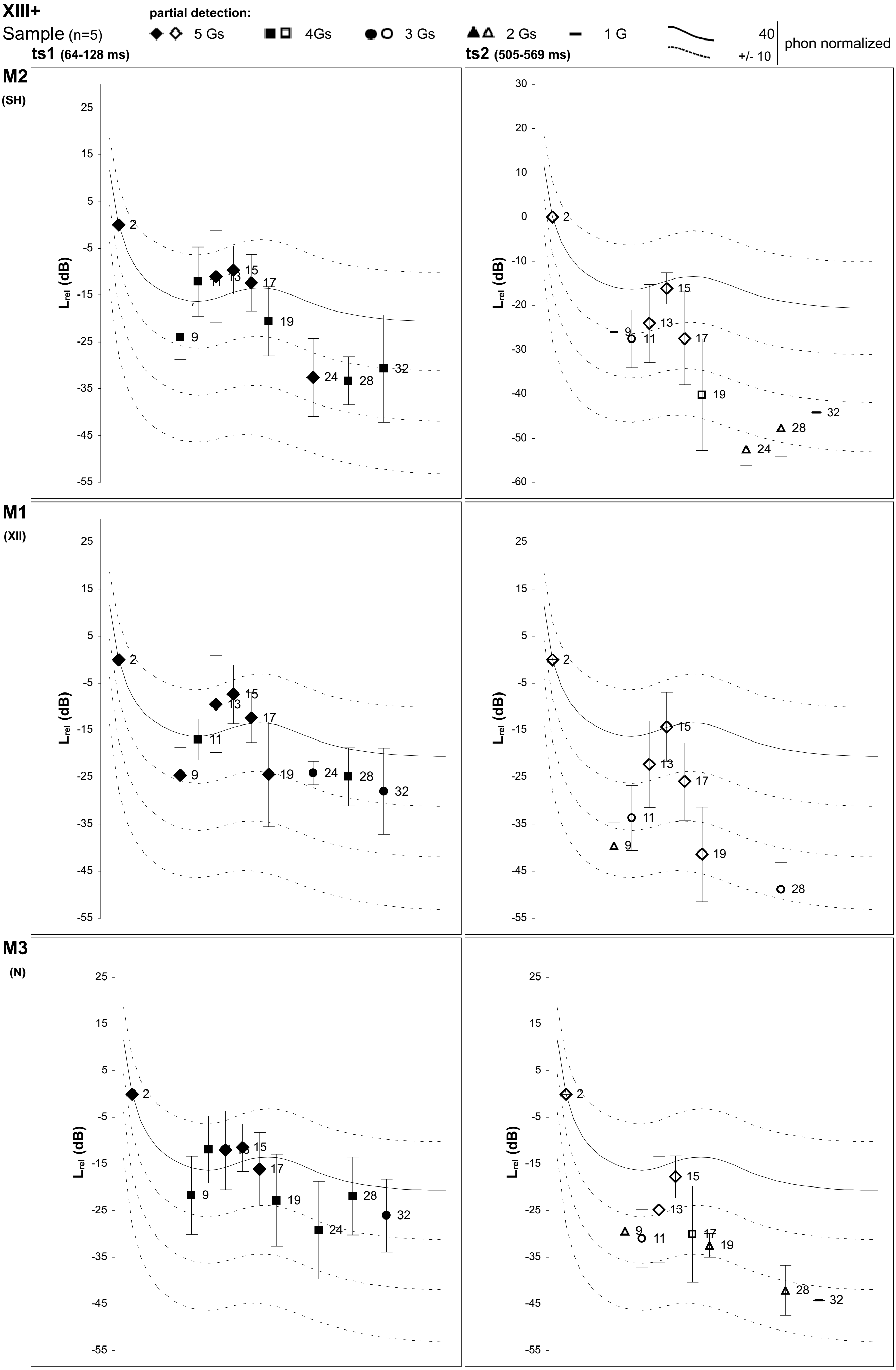
ts1 (64-128 ms) **ts2** (505-569 ms)

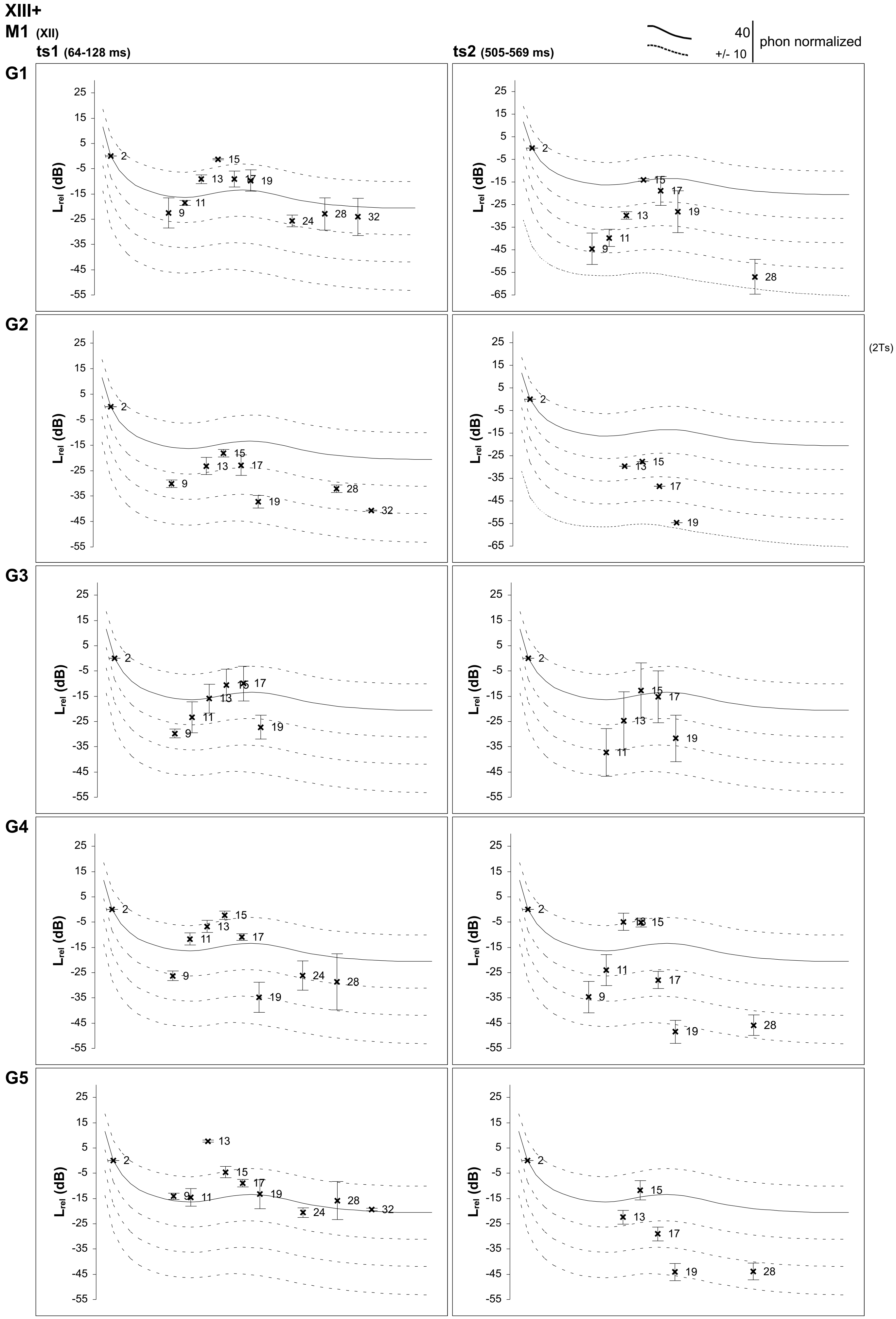


XIII

M3 (Neck)


ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
L_{rel} (dB)
25
15
5
-5
-15
-25
-35
-45
-55


XIII+
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
Lrel (dB)


XIII+
M1 (XII)
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
(2Ts)
L_rel (dB)

XIII+

M2 (Sound hole)

ts1 (64-128 ms) **ts2** (505-569 ms)

40 phon normalized

+/- 10

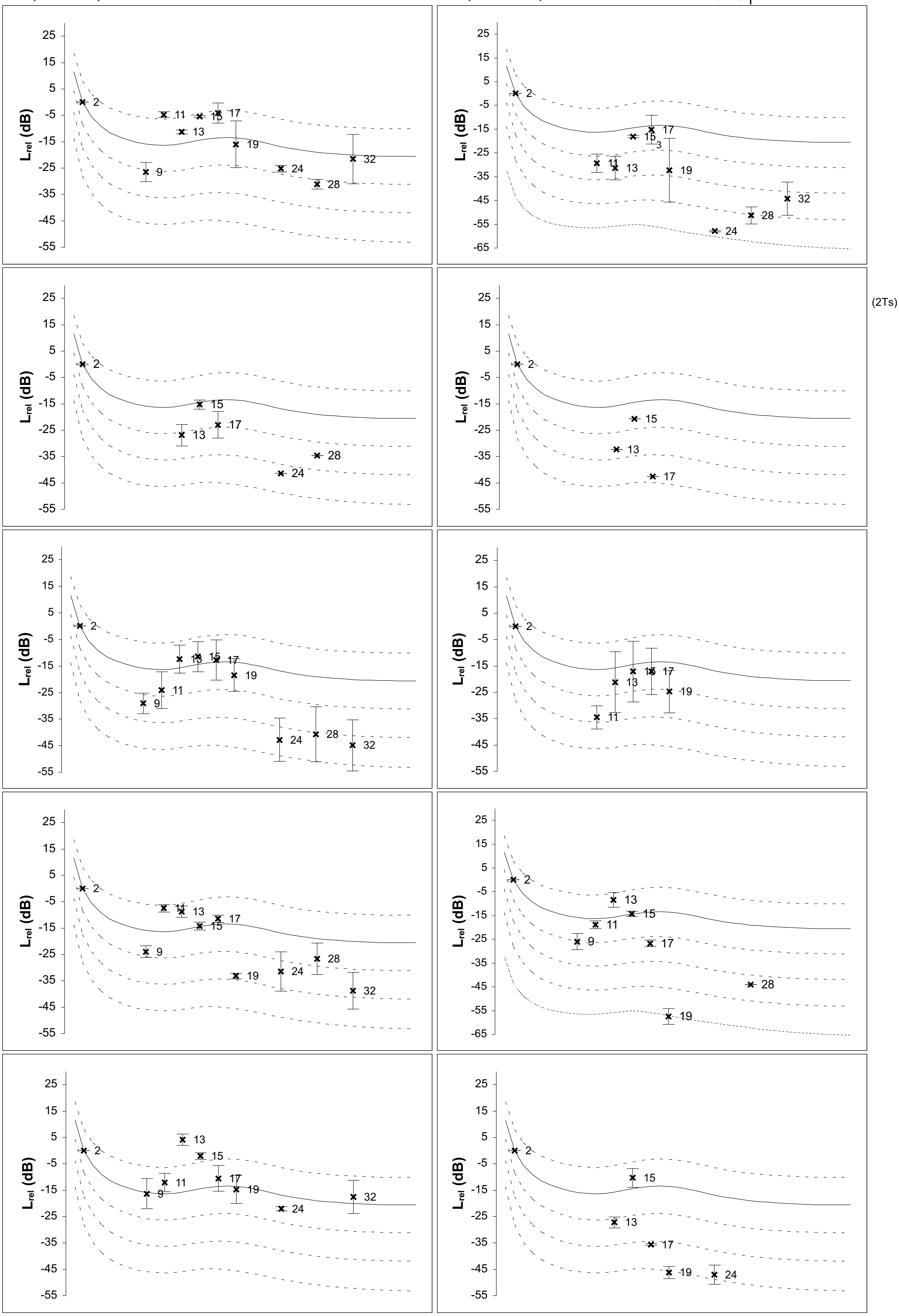
G1

G2

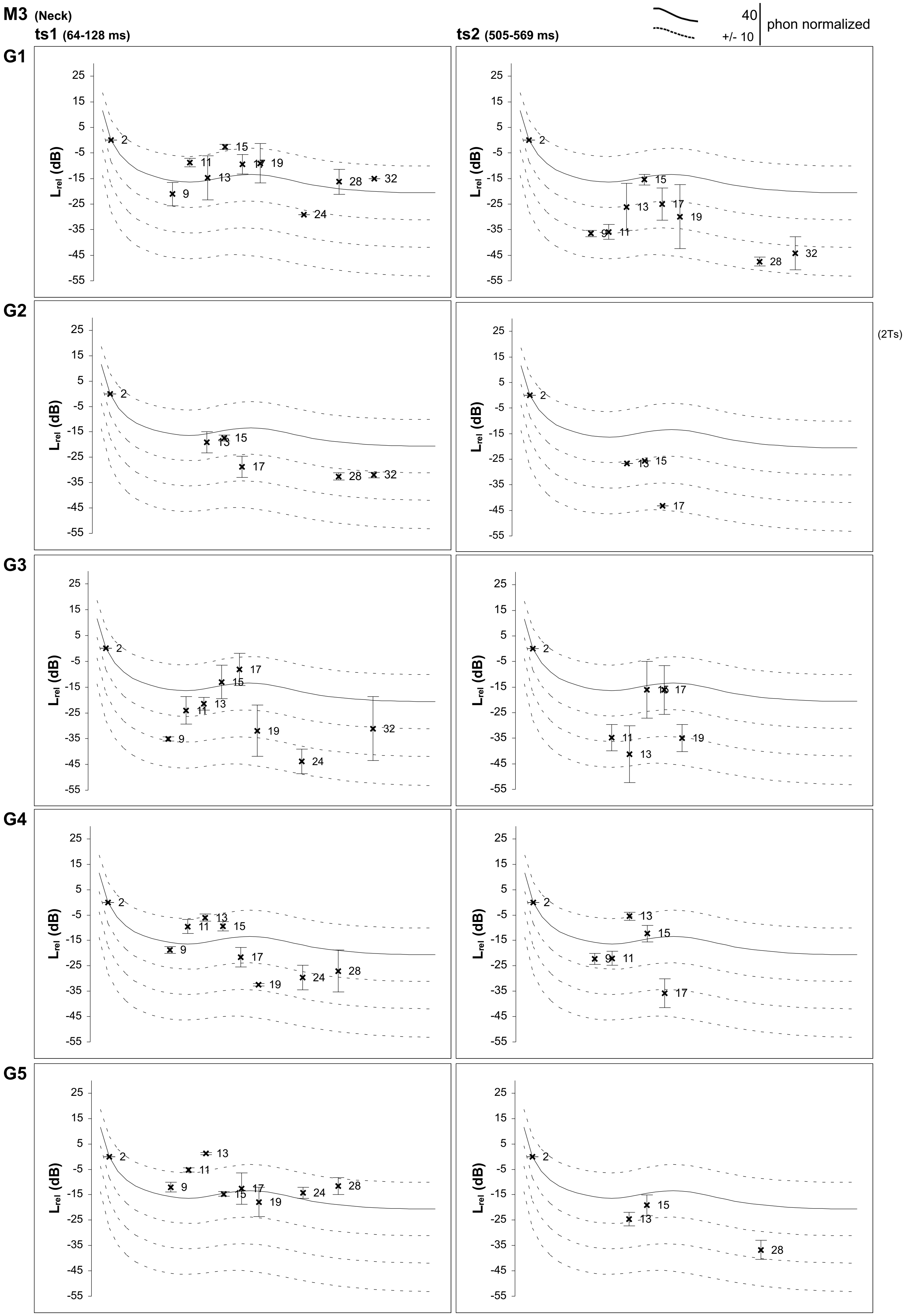
G3

G4

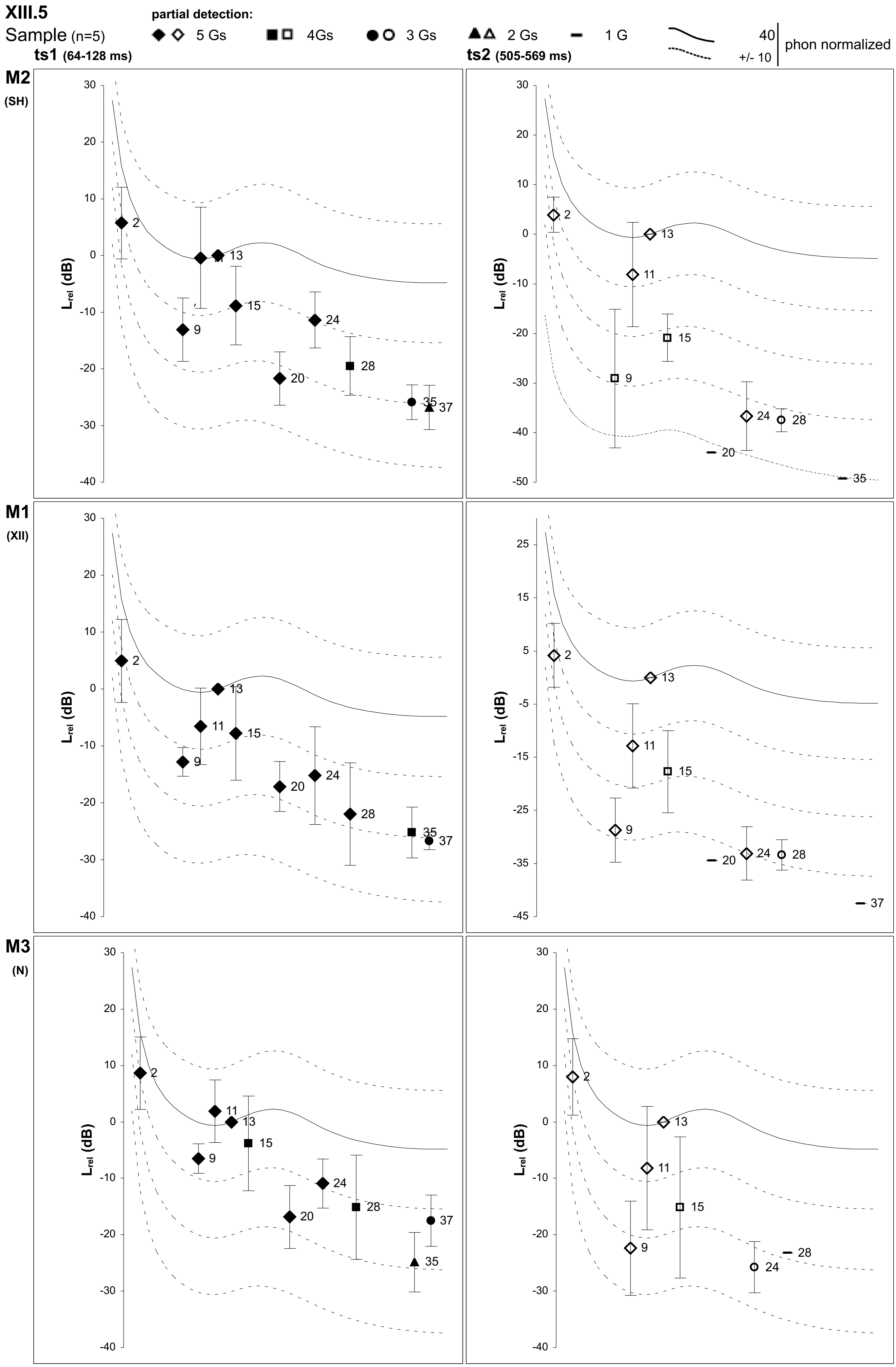
G5



XIII+



M3 (Neck)
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
(2Ts)
L_{rel} (dB)
25
15
5
-5
-15
-25
-35
-45
-55

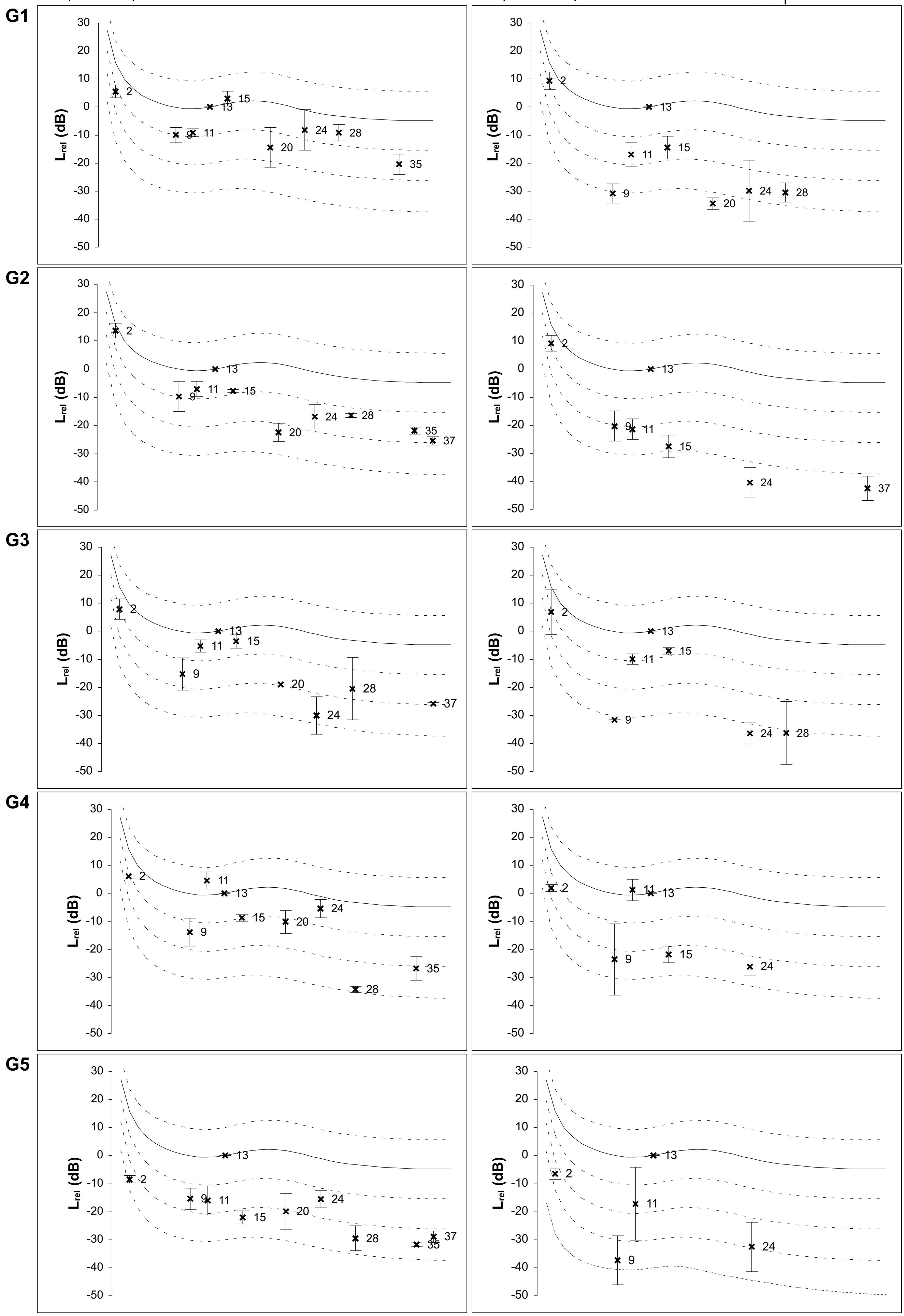

XIII.5
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_{rel} (dB)
2
9
11
13
15
20
24
28
35
37

XIII.5

M1 (XII)

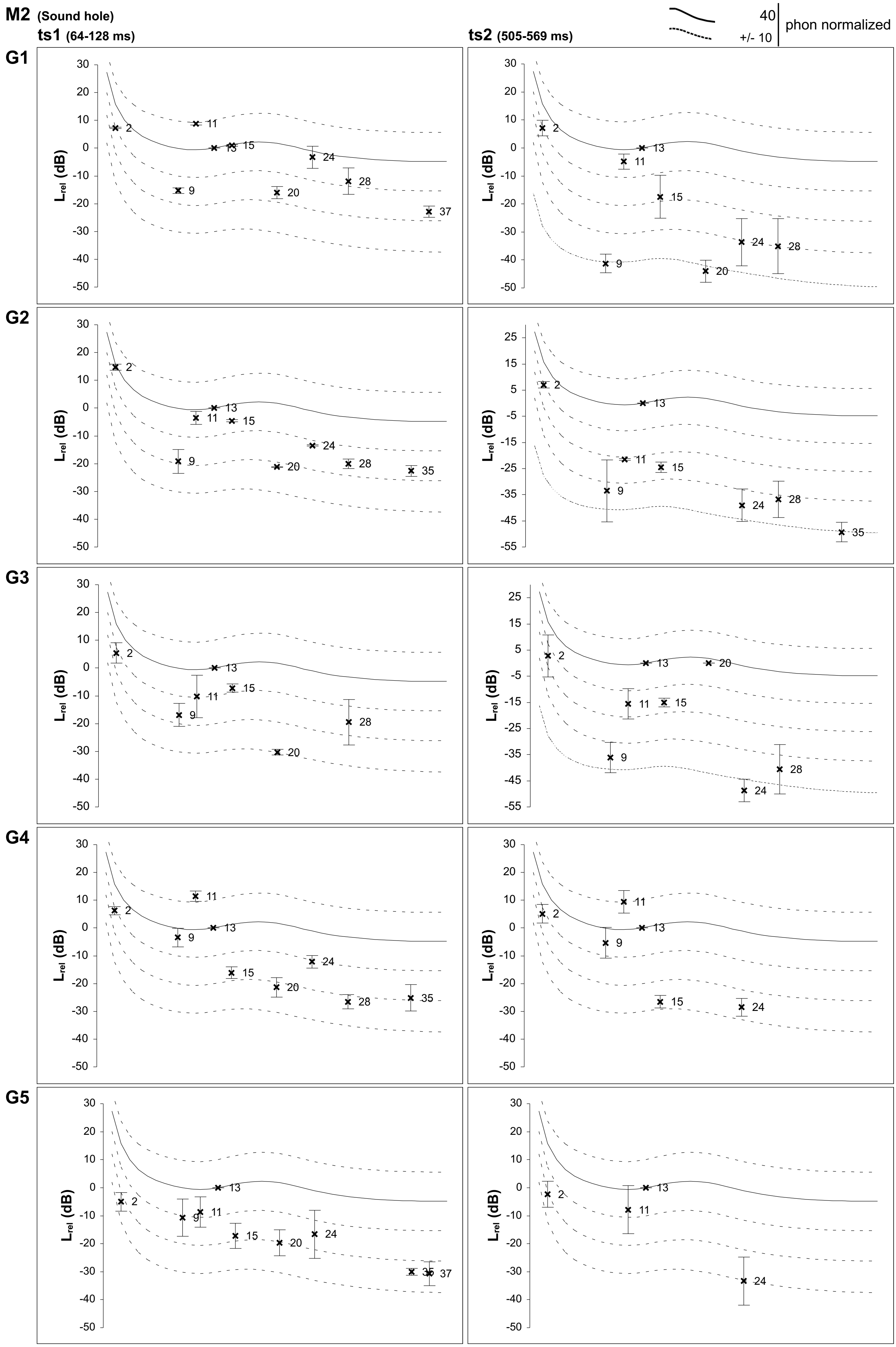
ts1 (64-128 ms) **ts2** (505-569 ms)

40 / +/- 10 phon normalized



XIII.5

M2 (Sound hole)



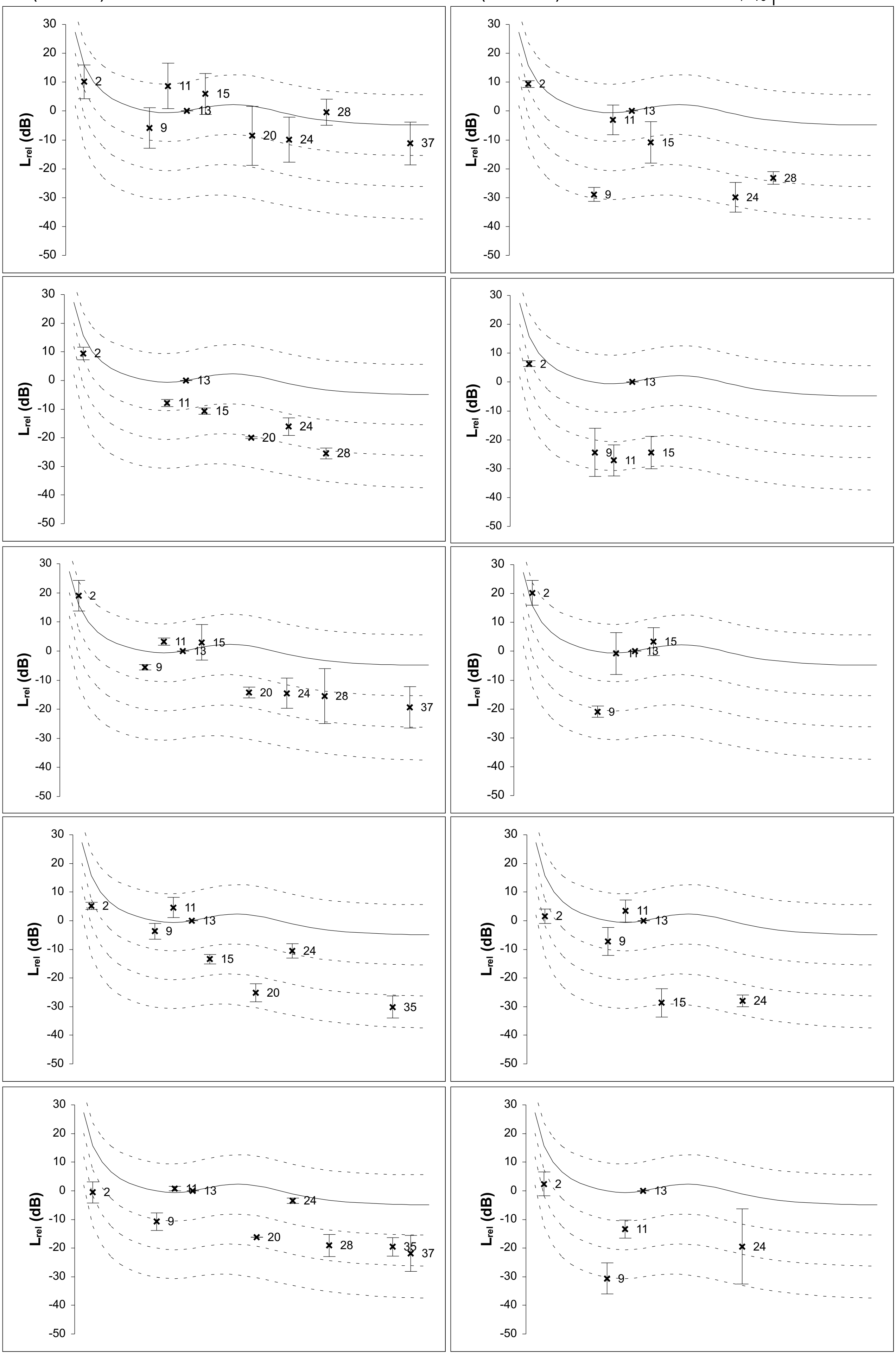
XIII.5

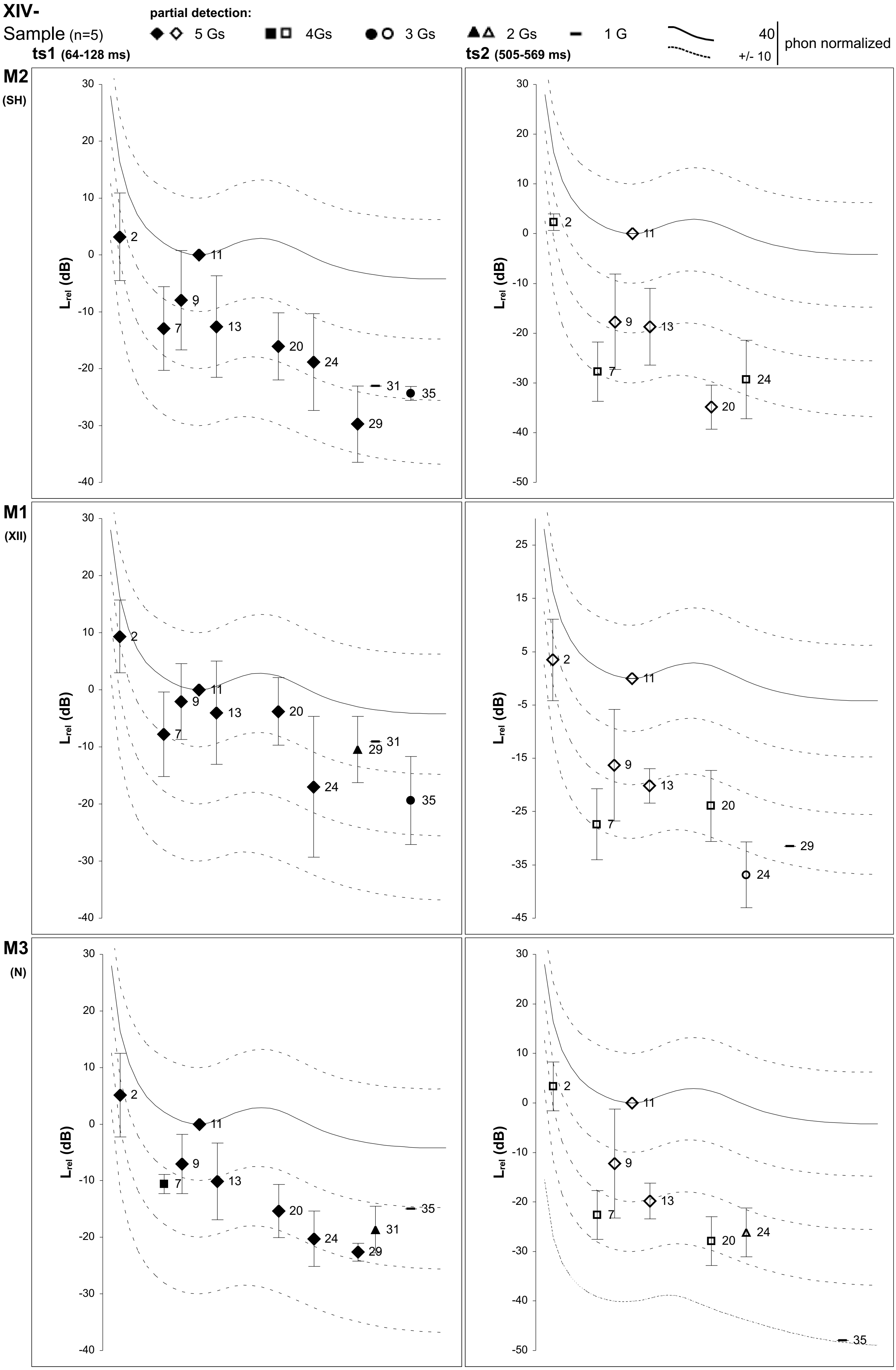
M3 (Neck)

40 — phon normalized
+/- 10 — phon normalized

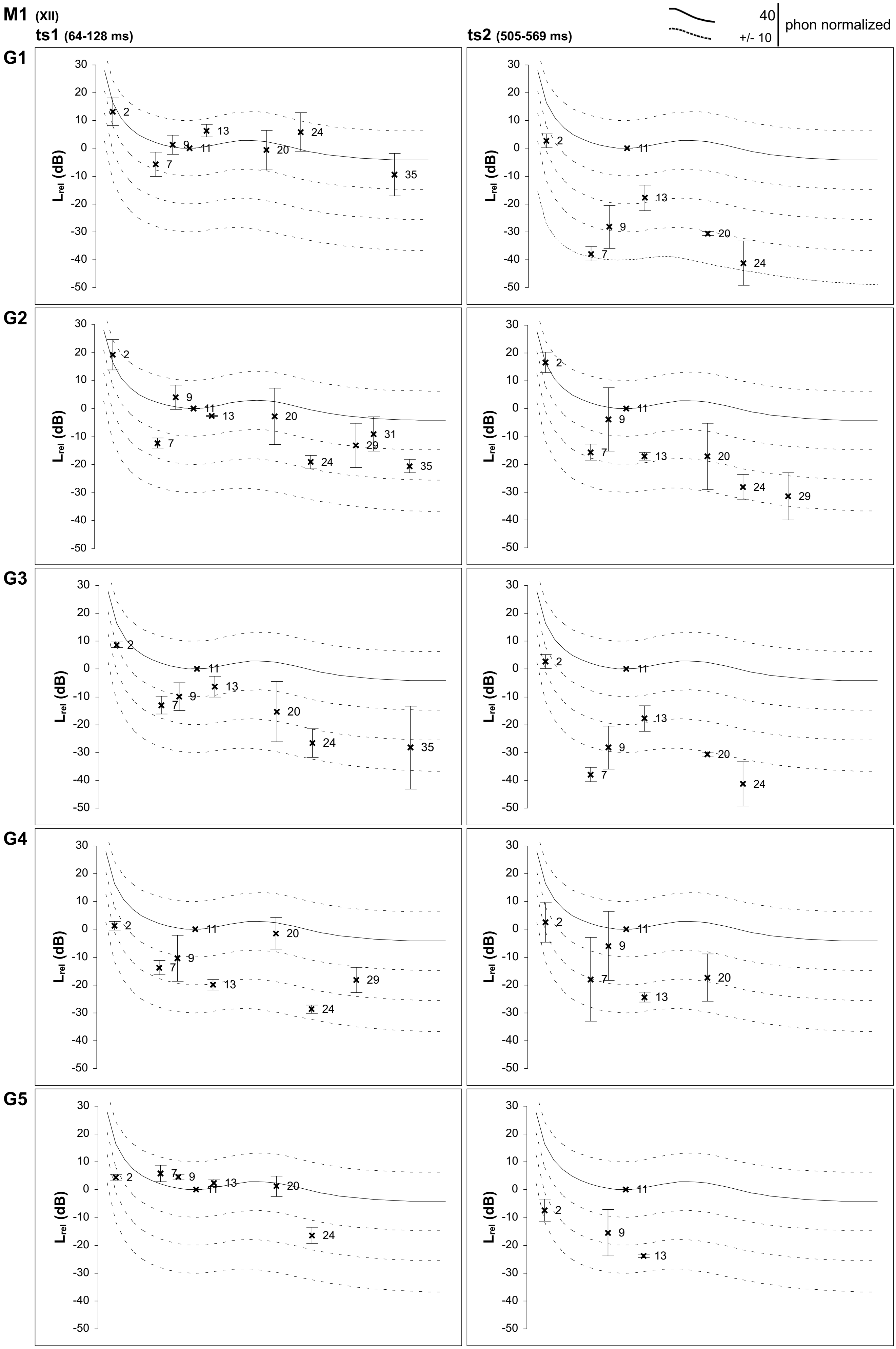
ts1 (64-128 ms) **ts2** (505-569 ms)

G1
G2
G3
G4
G5

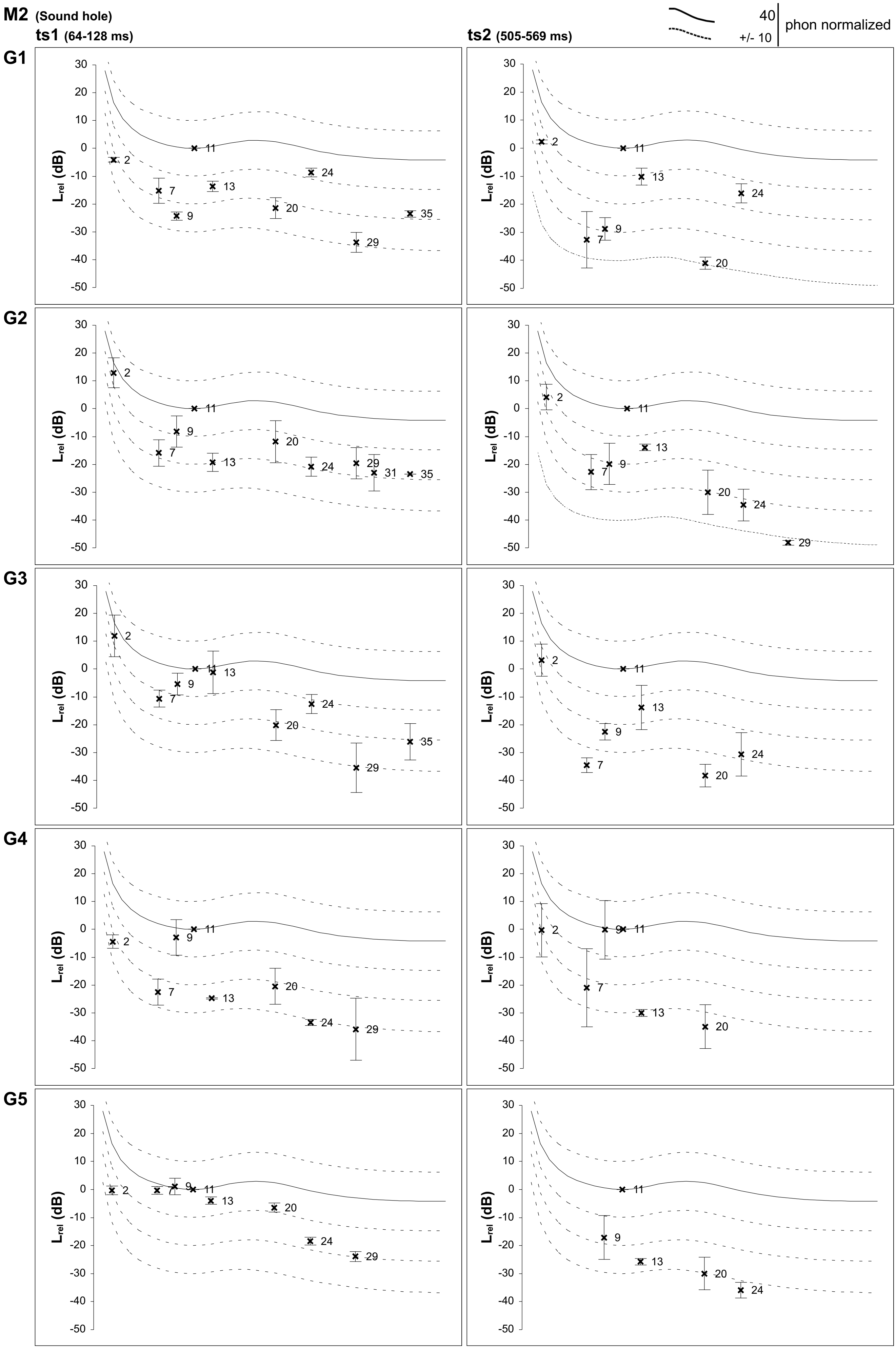



XIV-
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_{rel} (dB)

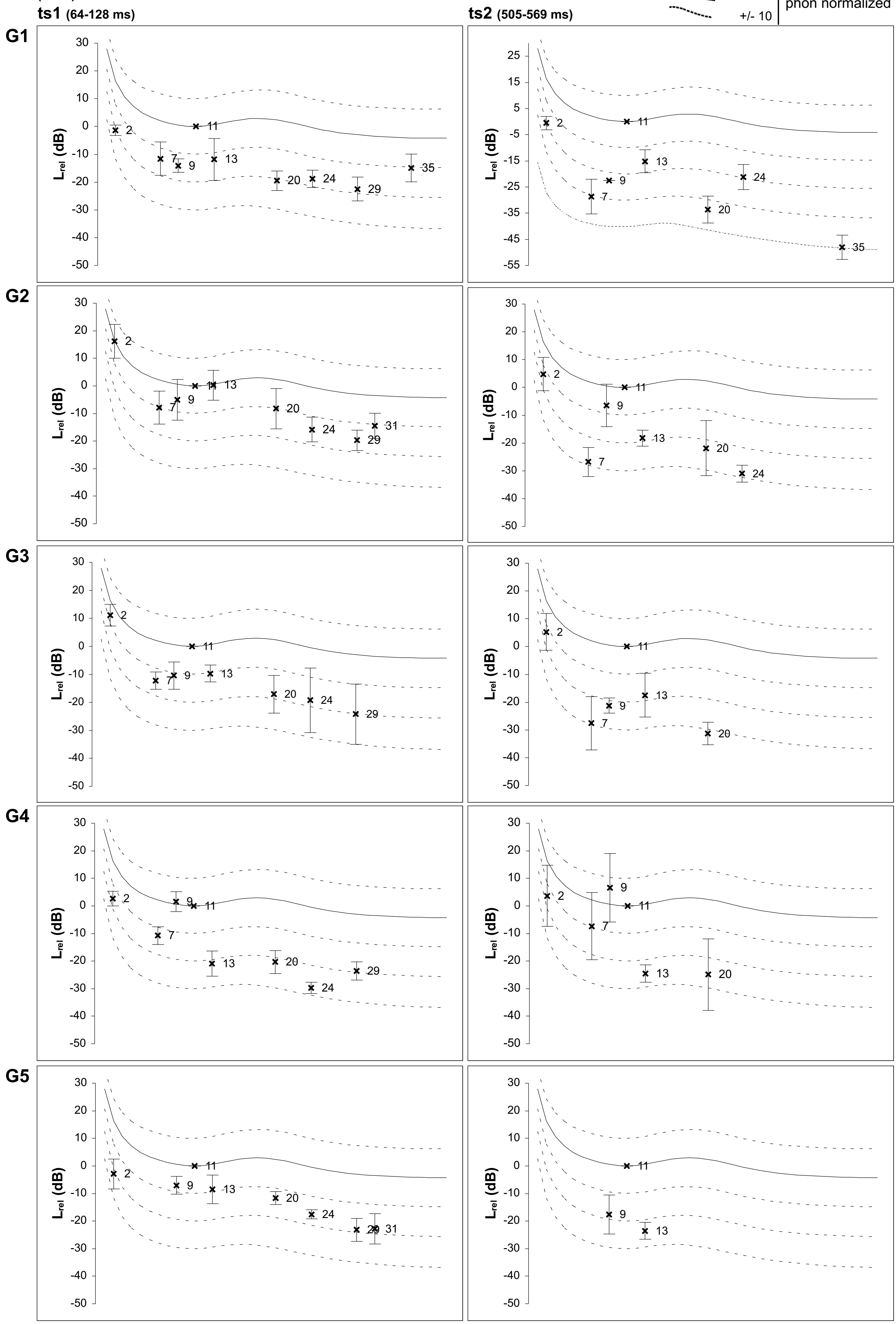
XIV-
M1 (XII)


ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
L_{rel} (dB)

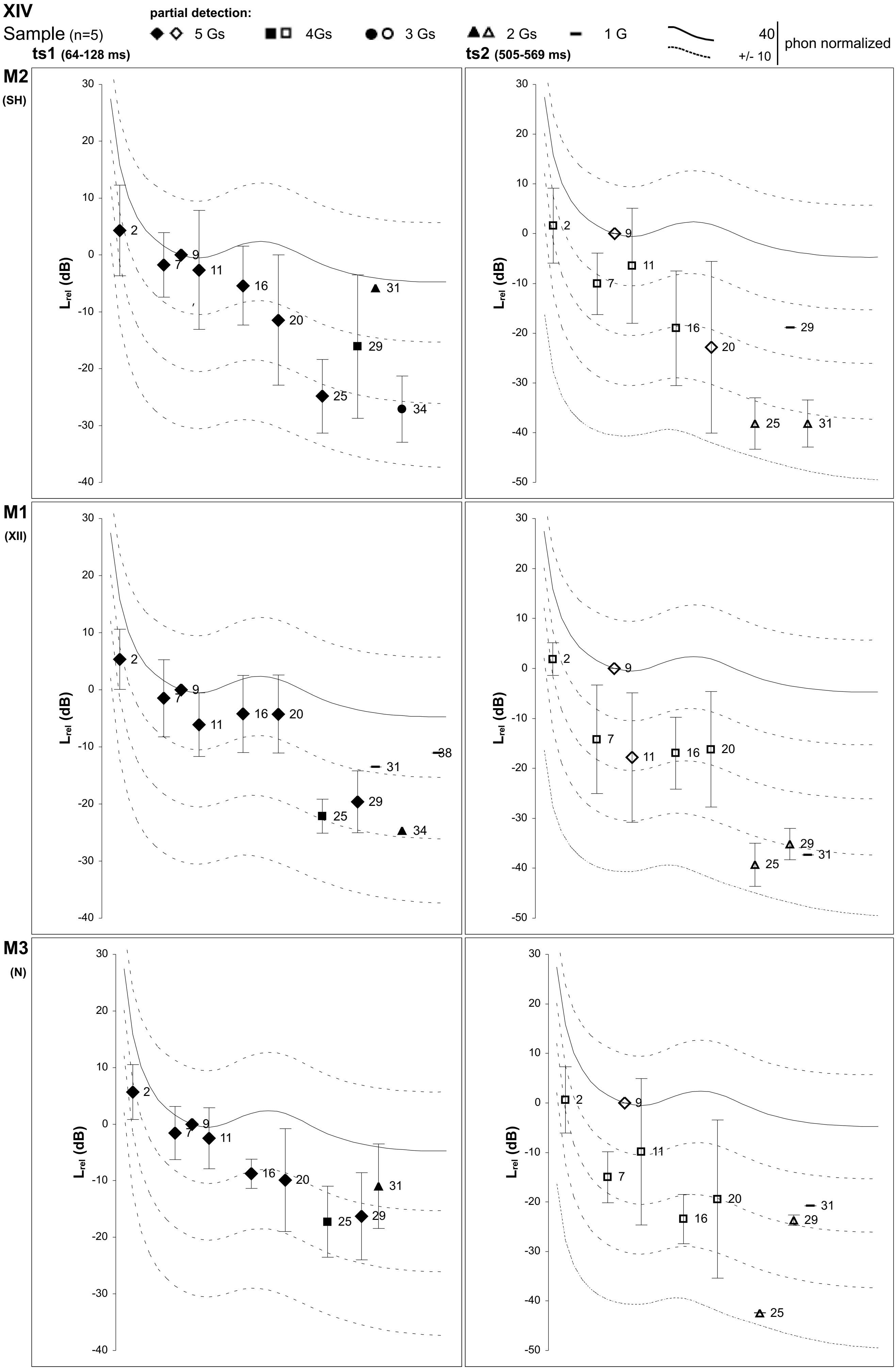
XIV-
M2 (Sound hole)



XIV-
M3 (Neck)



ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
L_rel (dB)

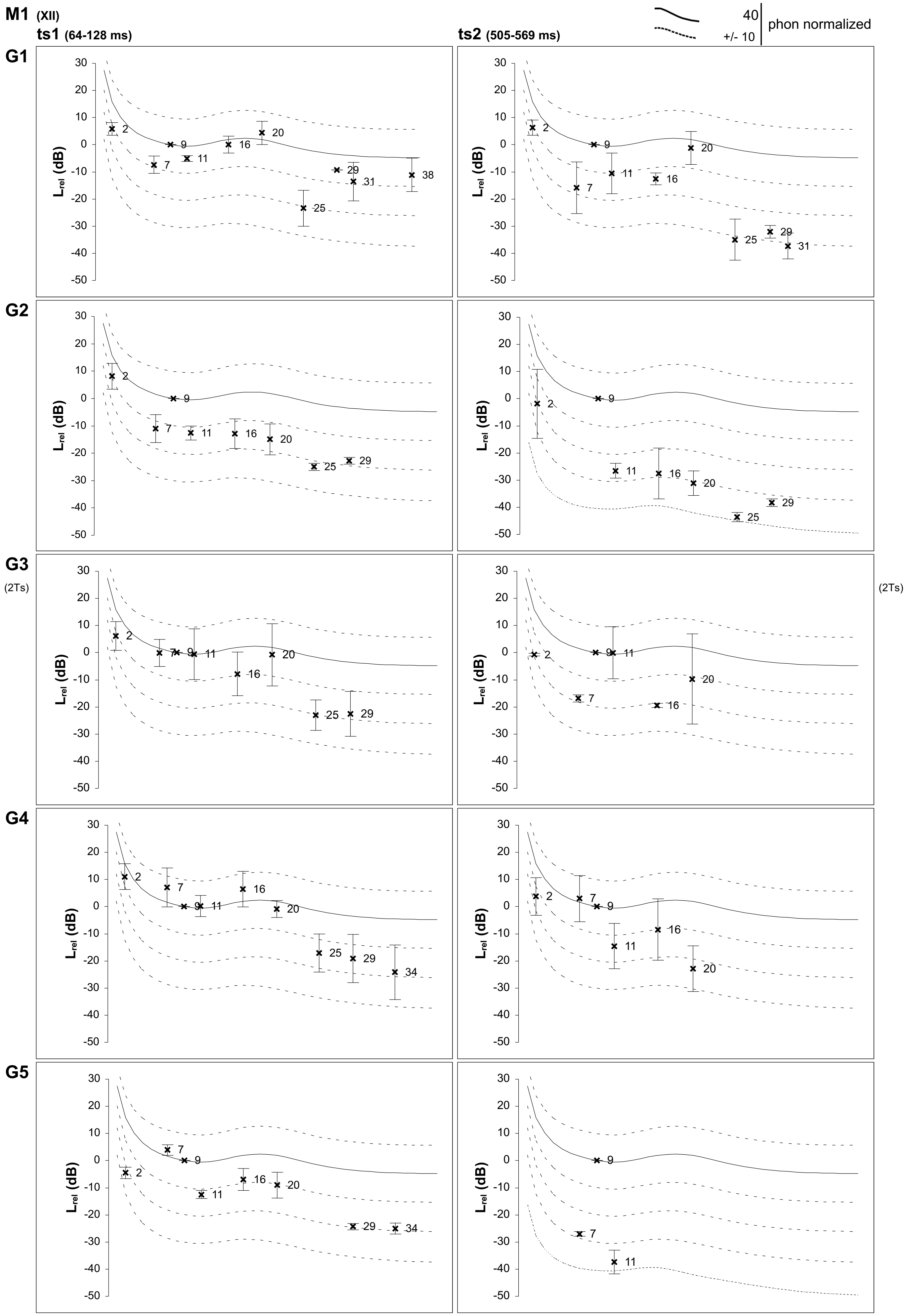


XIV
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_rel (dB)

XIV

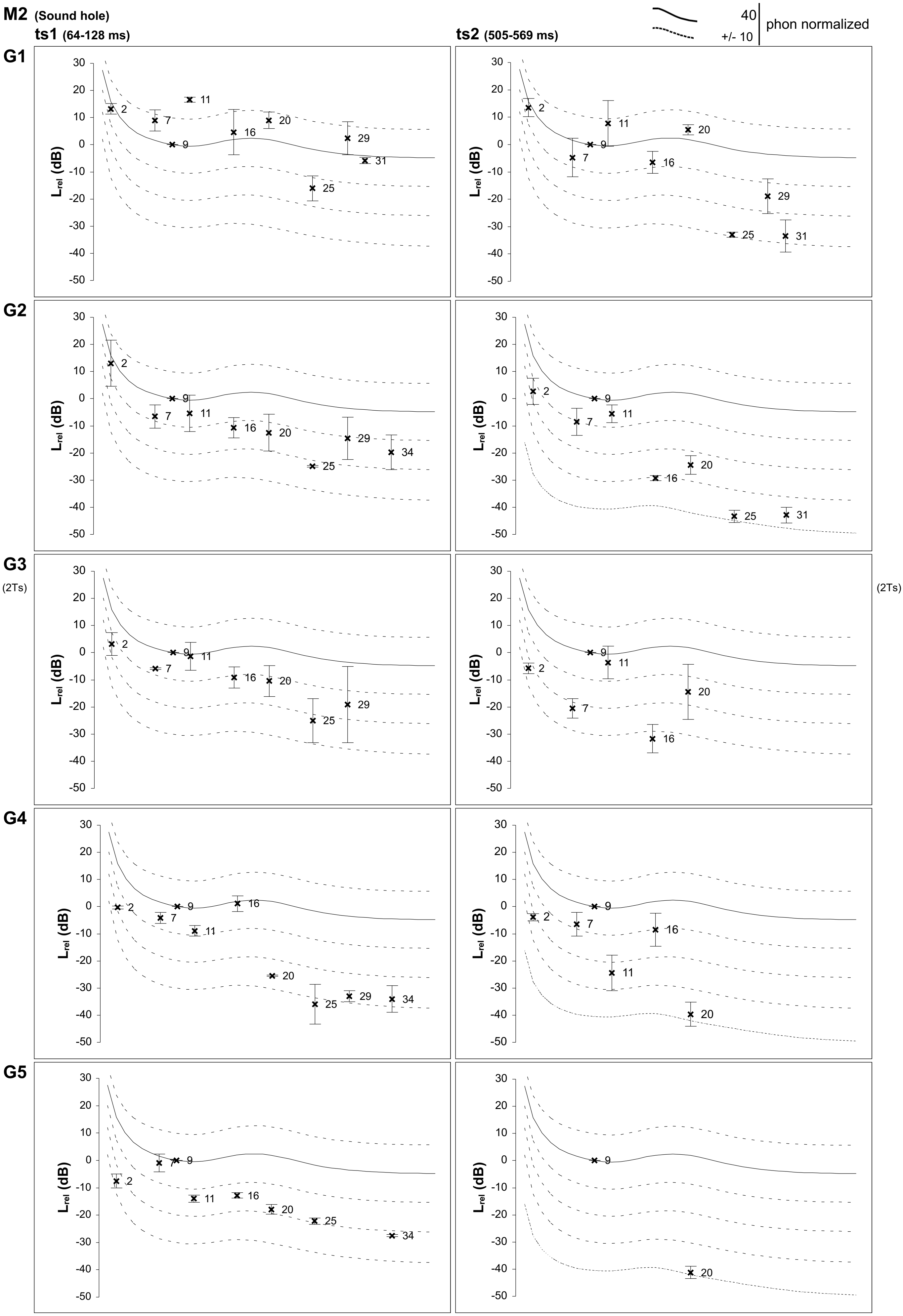
M1 (XII)

ts1 (64-128 ms) **ts2** (505-569 ms)



XIV

M2 (Sound hole)



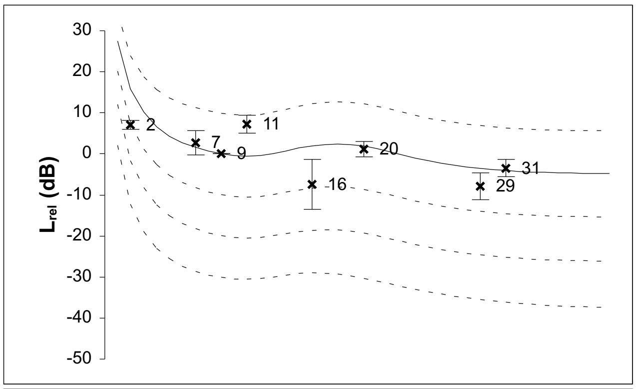
XIV

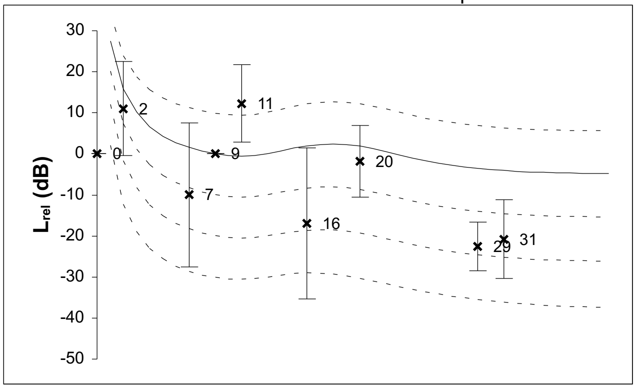
M3 (Neck)

40 | phon normalized
+/- 10

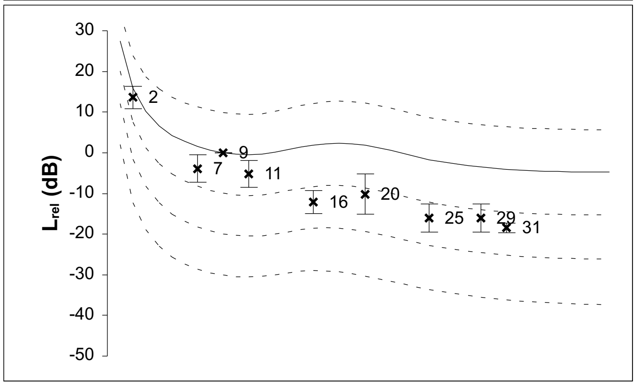
ts1 (64-128 ms) | **ts2** (505-569 ms)

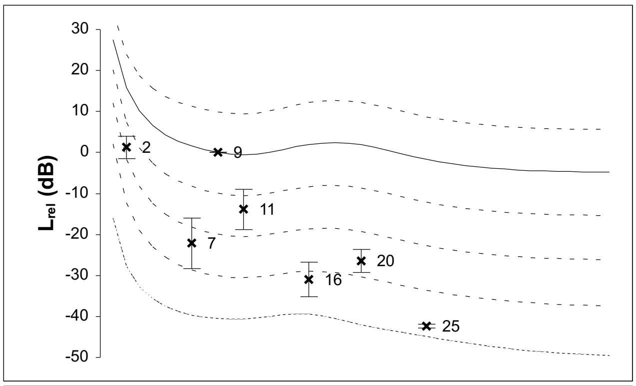
G1





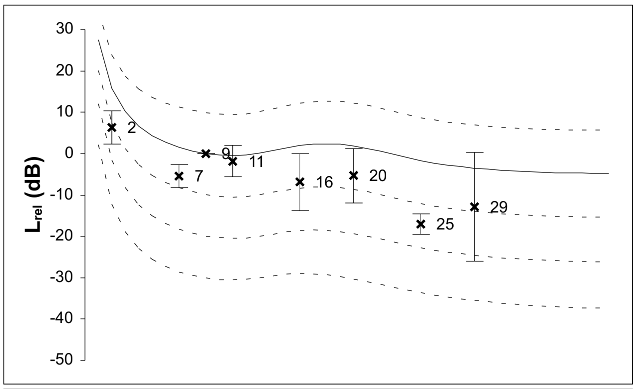
G2

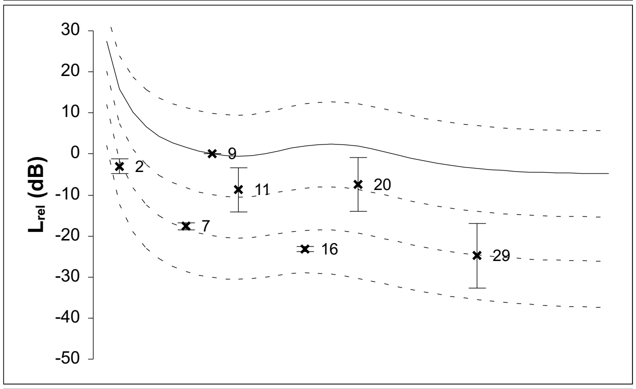




G3

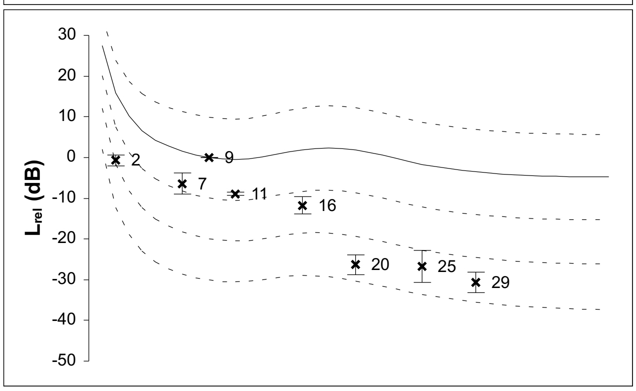
(2Ts)

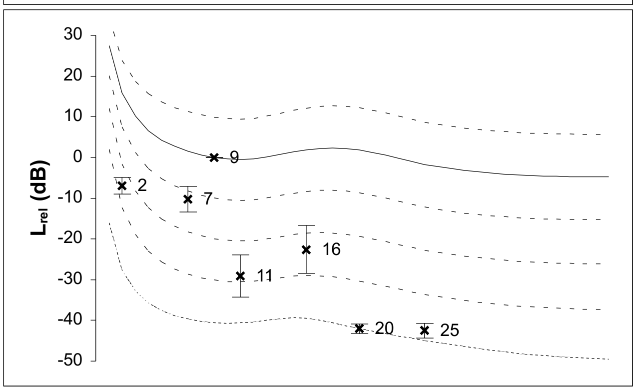




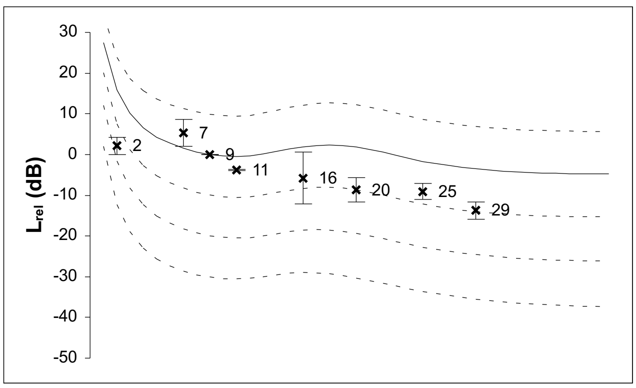
(2Ts)

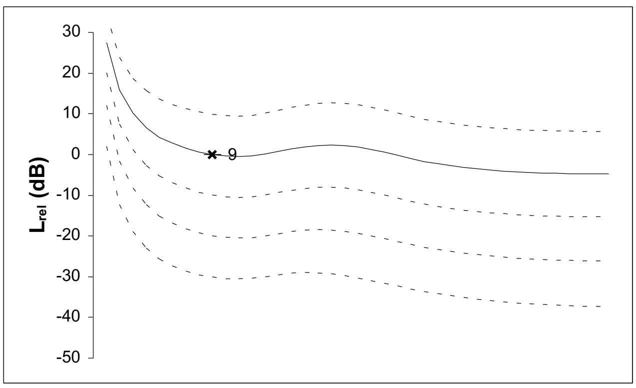
G4

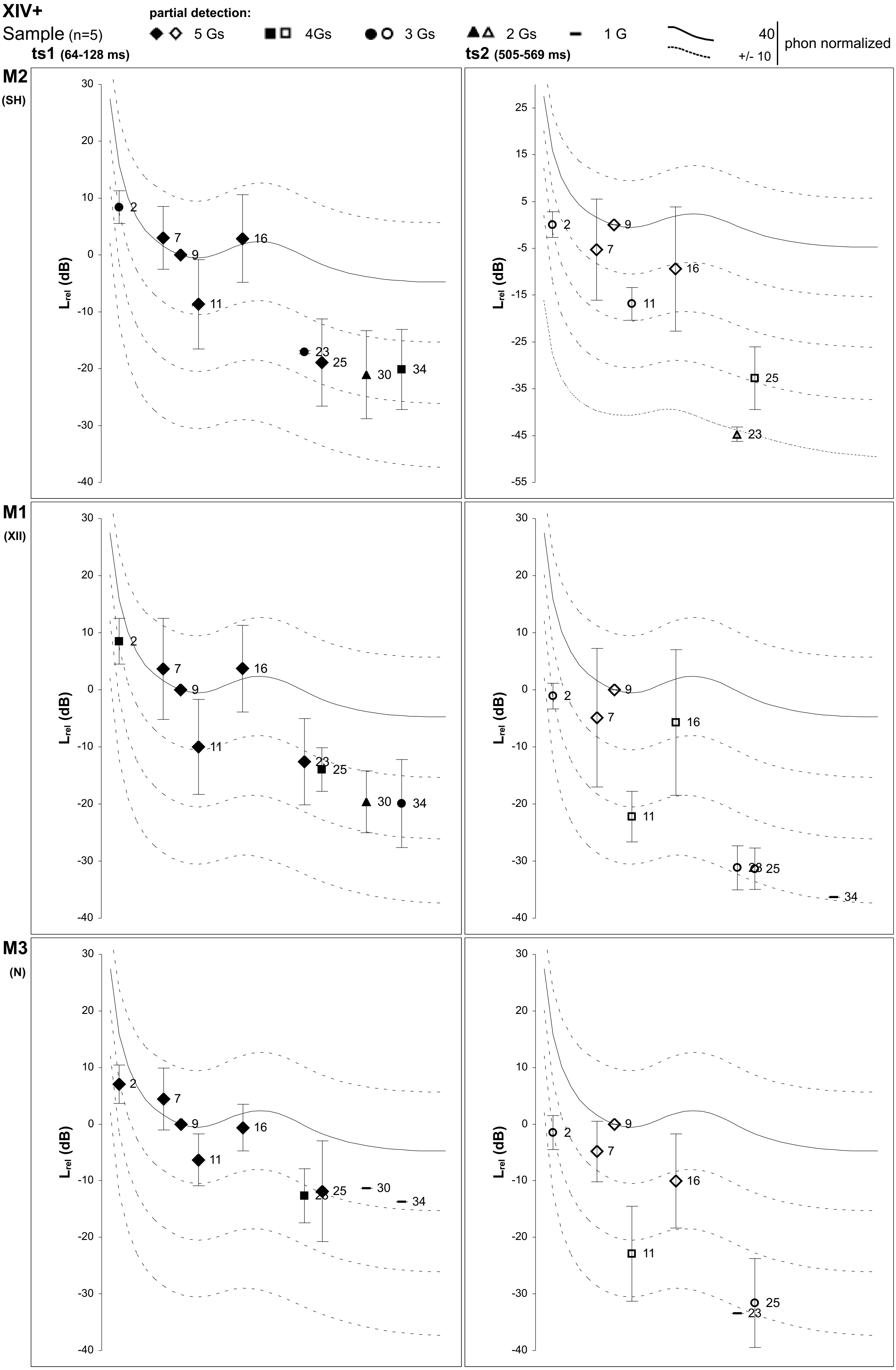




G5






XIV+
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_{rel} (dB)

XIV+

M1 **(XII)**

ts1 **(64-128 ms)** **ts2** **(505-569 ms)**

40 / +/- 10 phon normalized

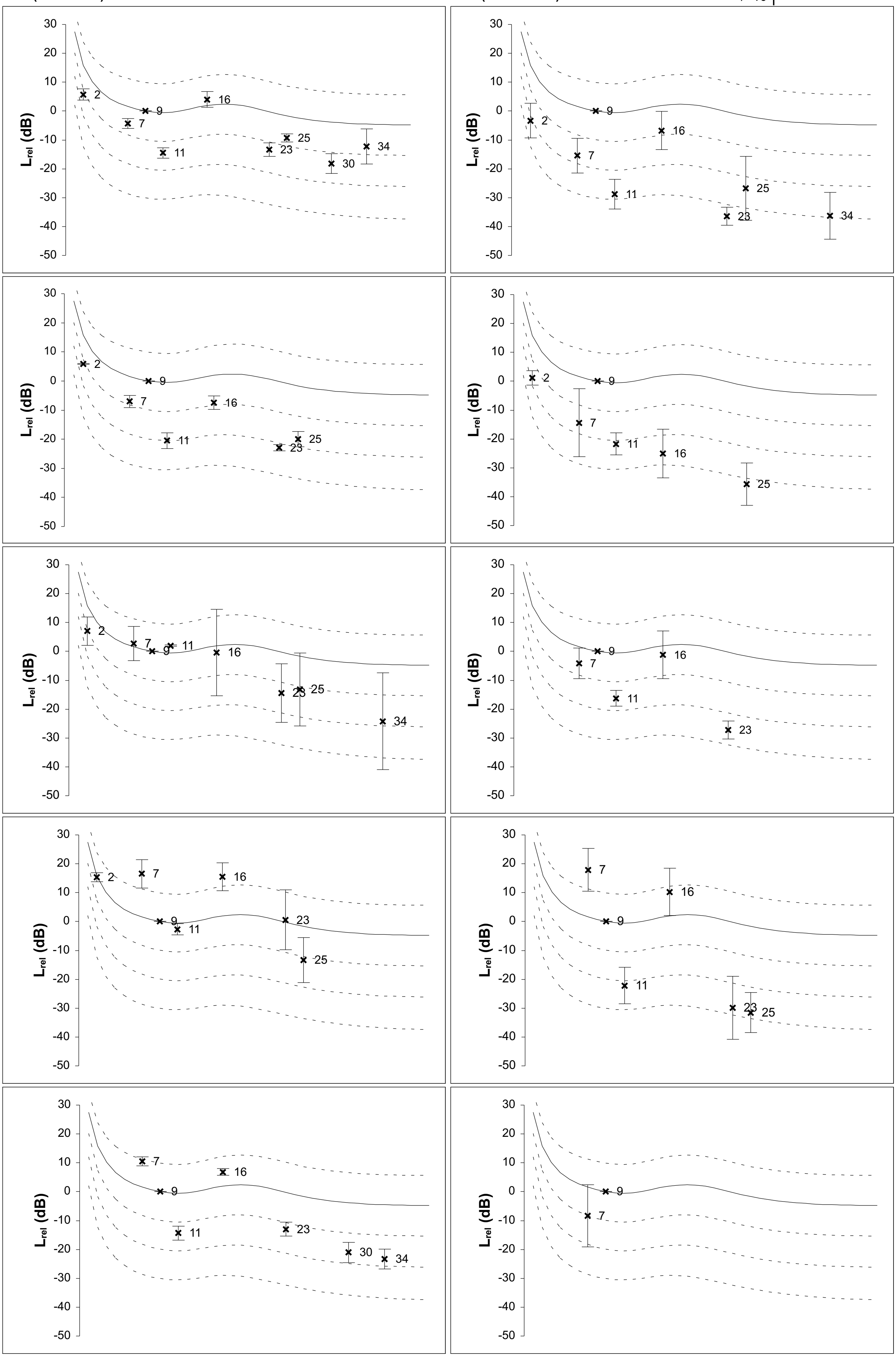
G1

G2

G3

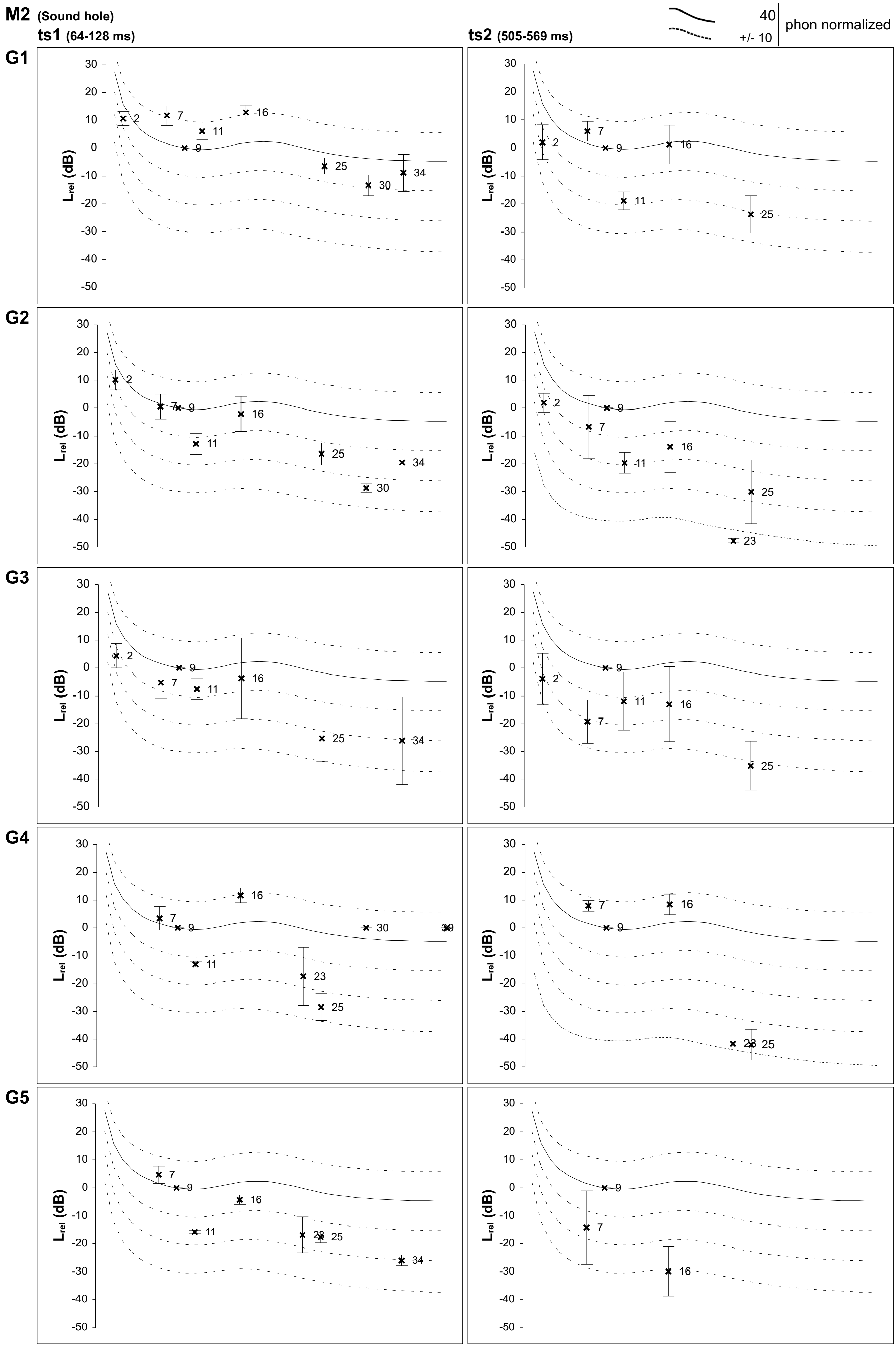
G4

G5



XIV+

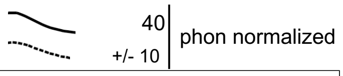
M2 (Sound hole)



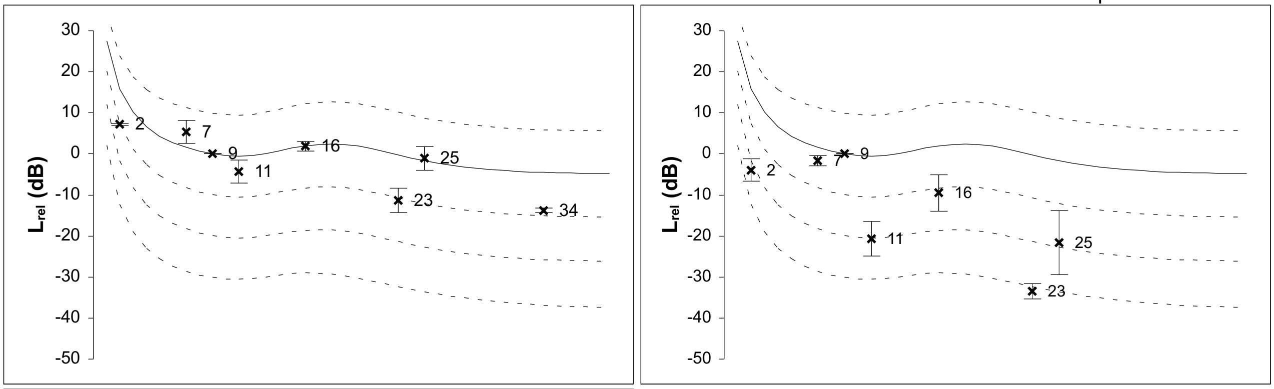
XIV+

M3 (Neck)

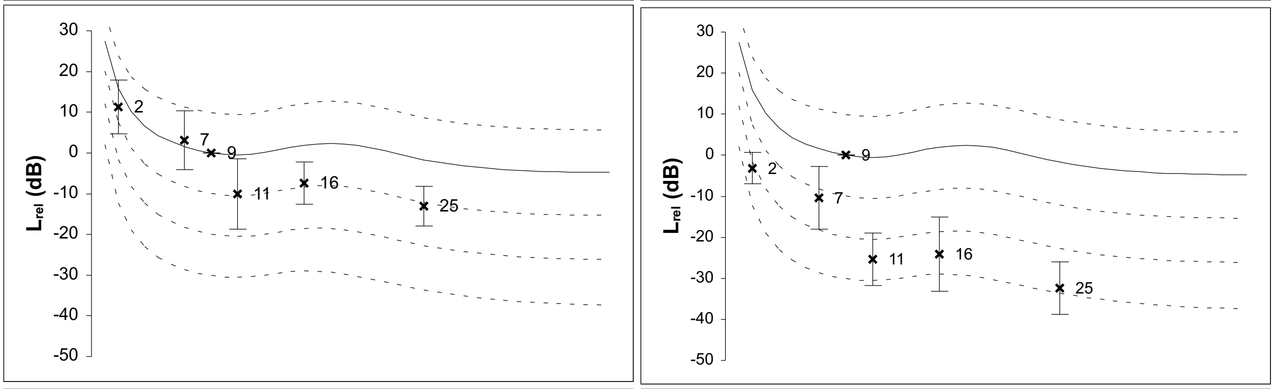
ts1 (64-128 ms) **ts2** (505-569 ms)



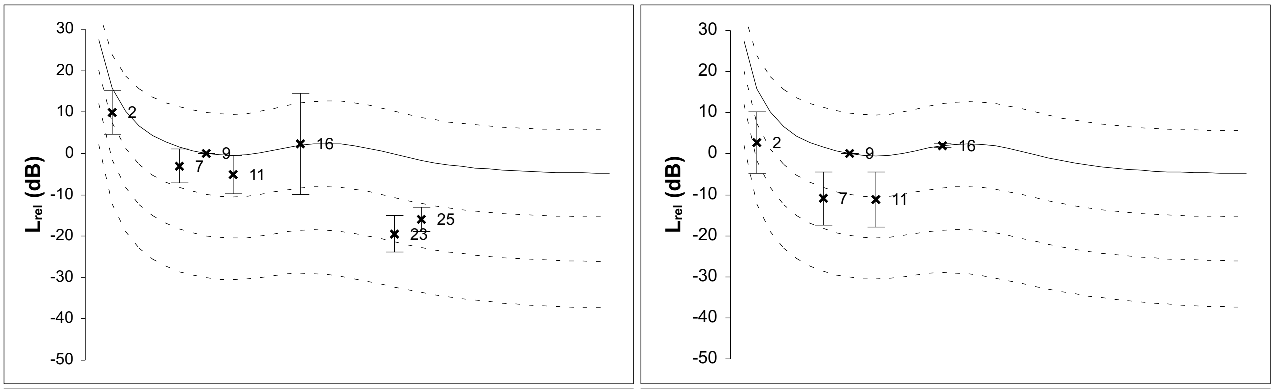
G1



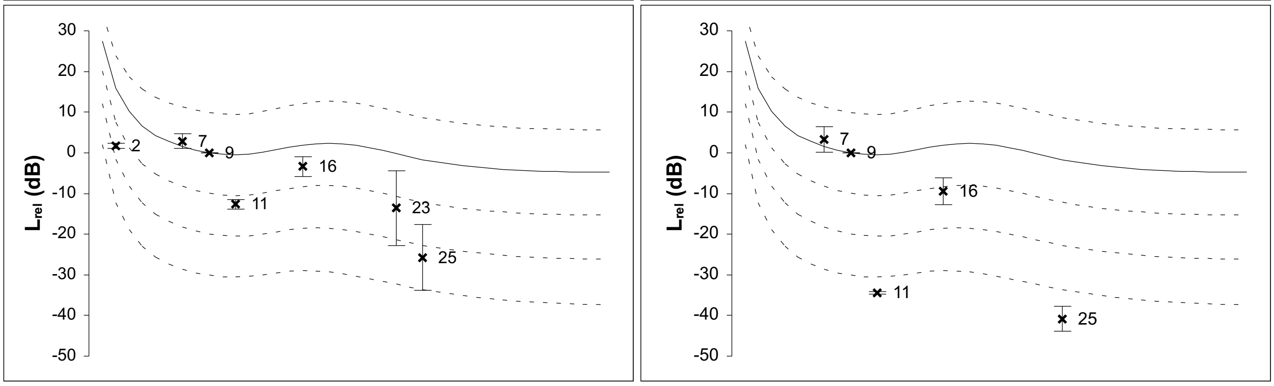
G2



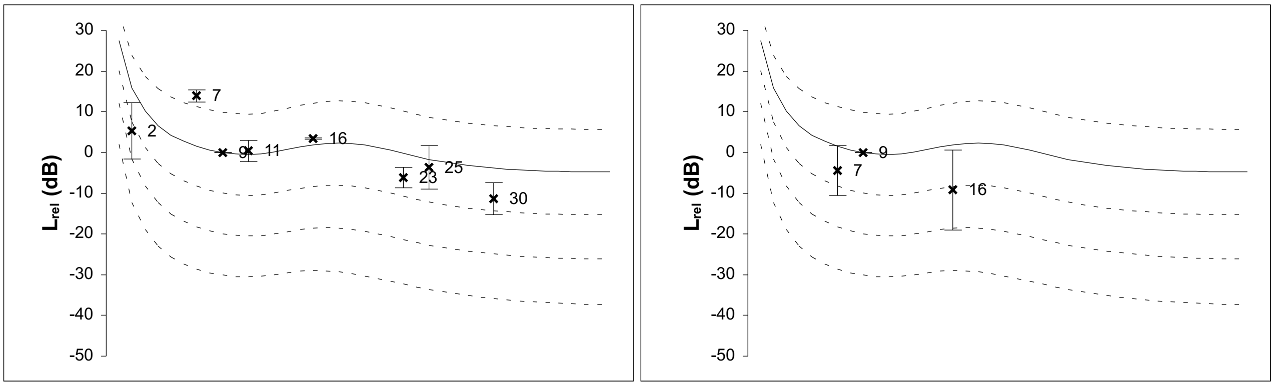
G3



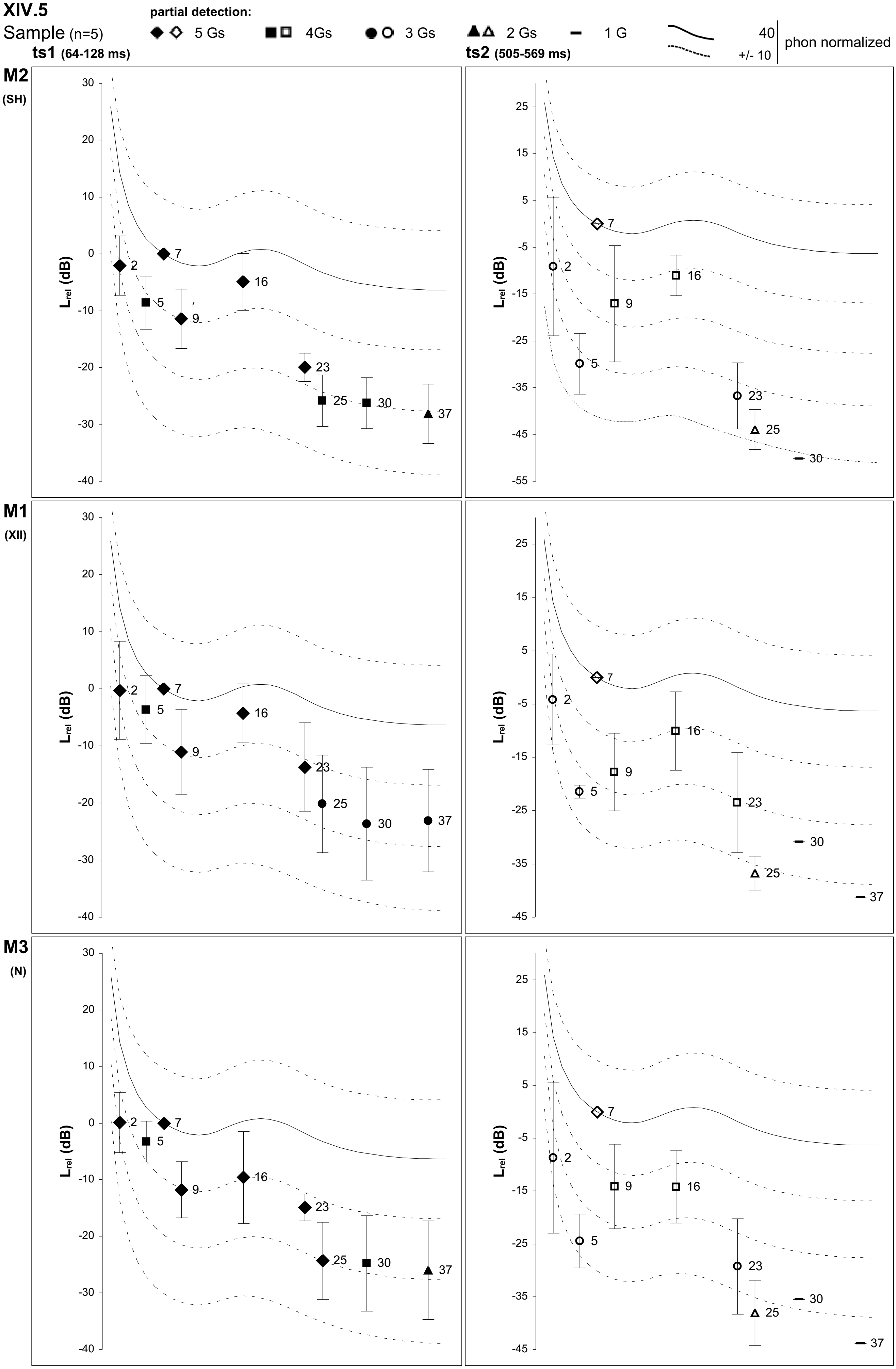
G4



G5



XIV.5

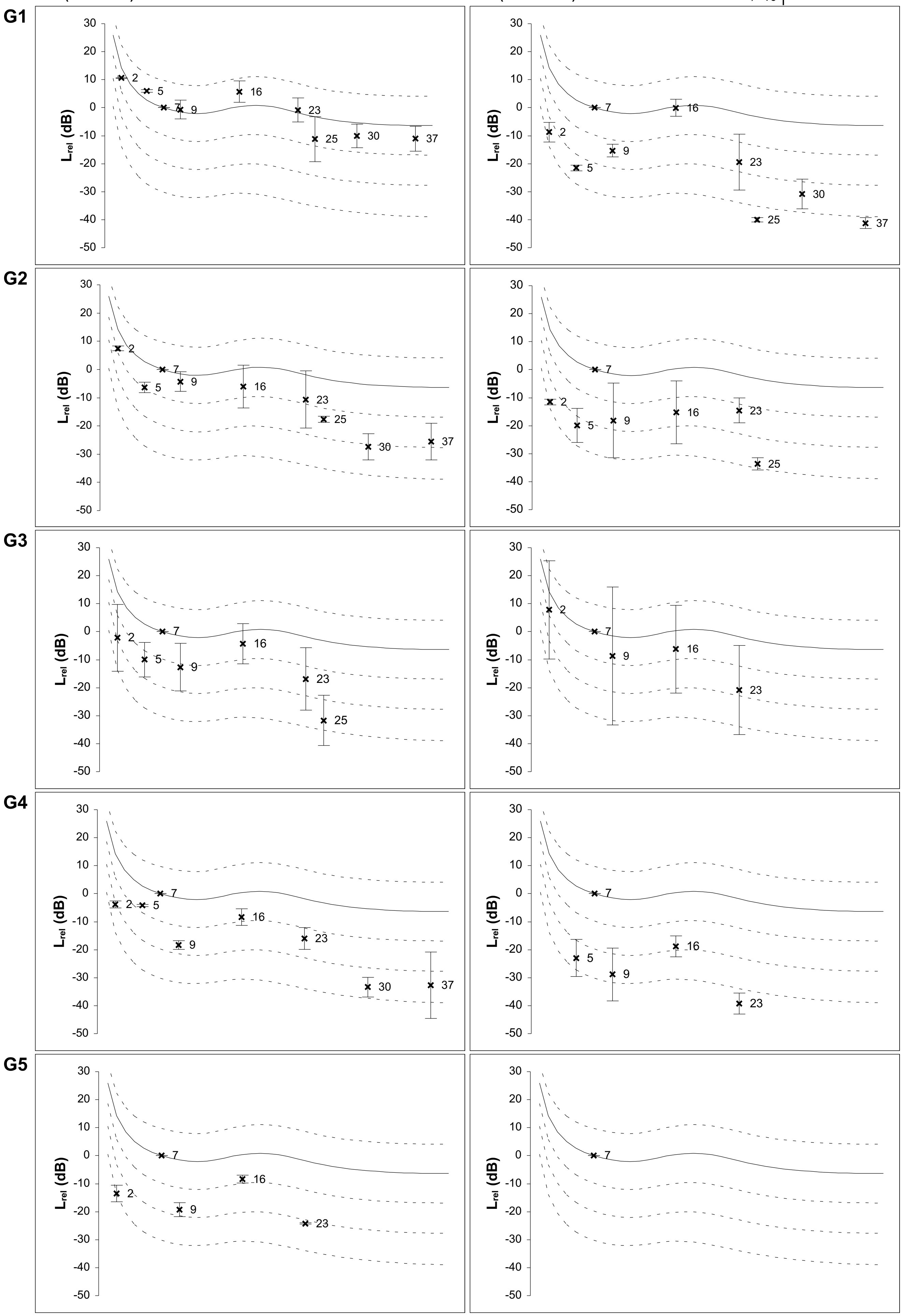

Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_{rel} (dB)

XIV.5

M1 (XII)

ts1 (64-128 ms) **ts2** (505-569 ms)

40 phon normalized
+/- 10



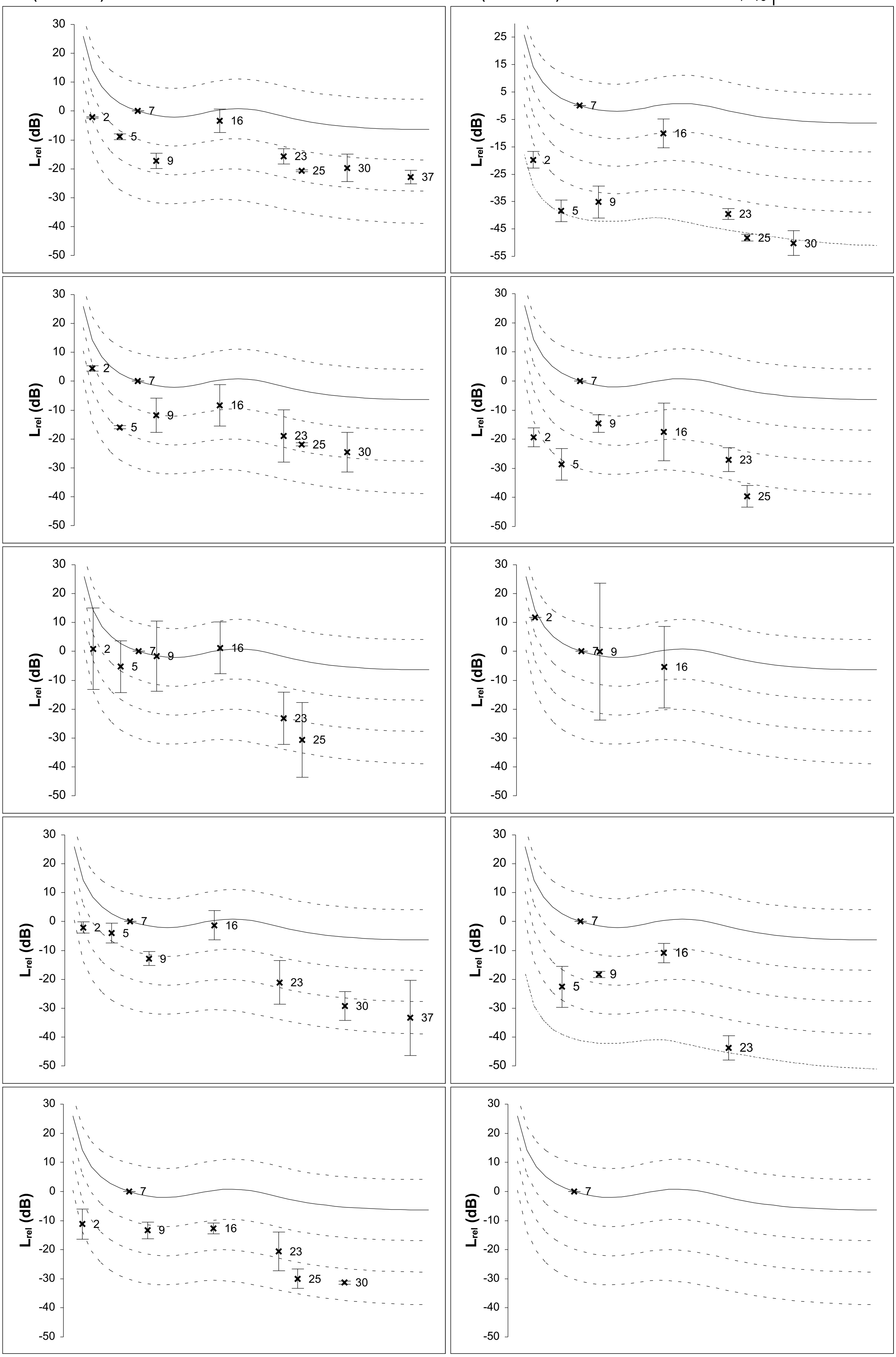
XIV.5

M2 (Sound hole)

ts1 (64-128 ms) **ts2** (505-569 ms)

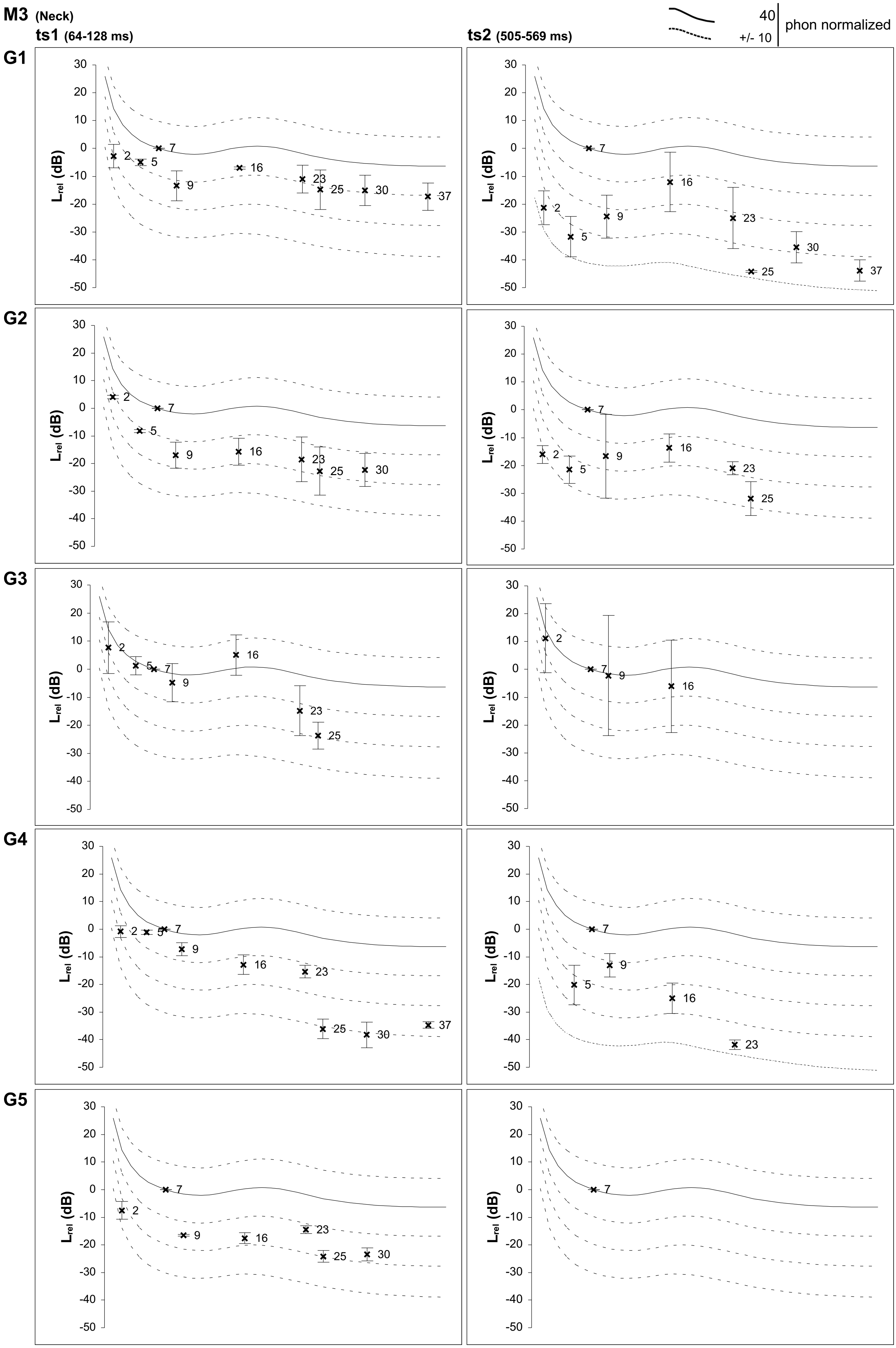
40 / +/- 10 | phon normalized

G1
G2
G3
G4
G5



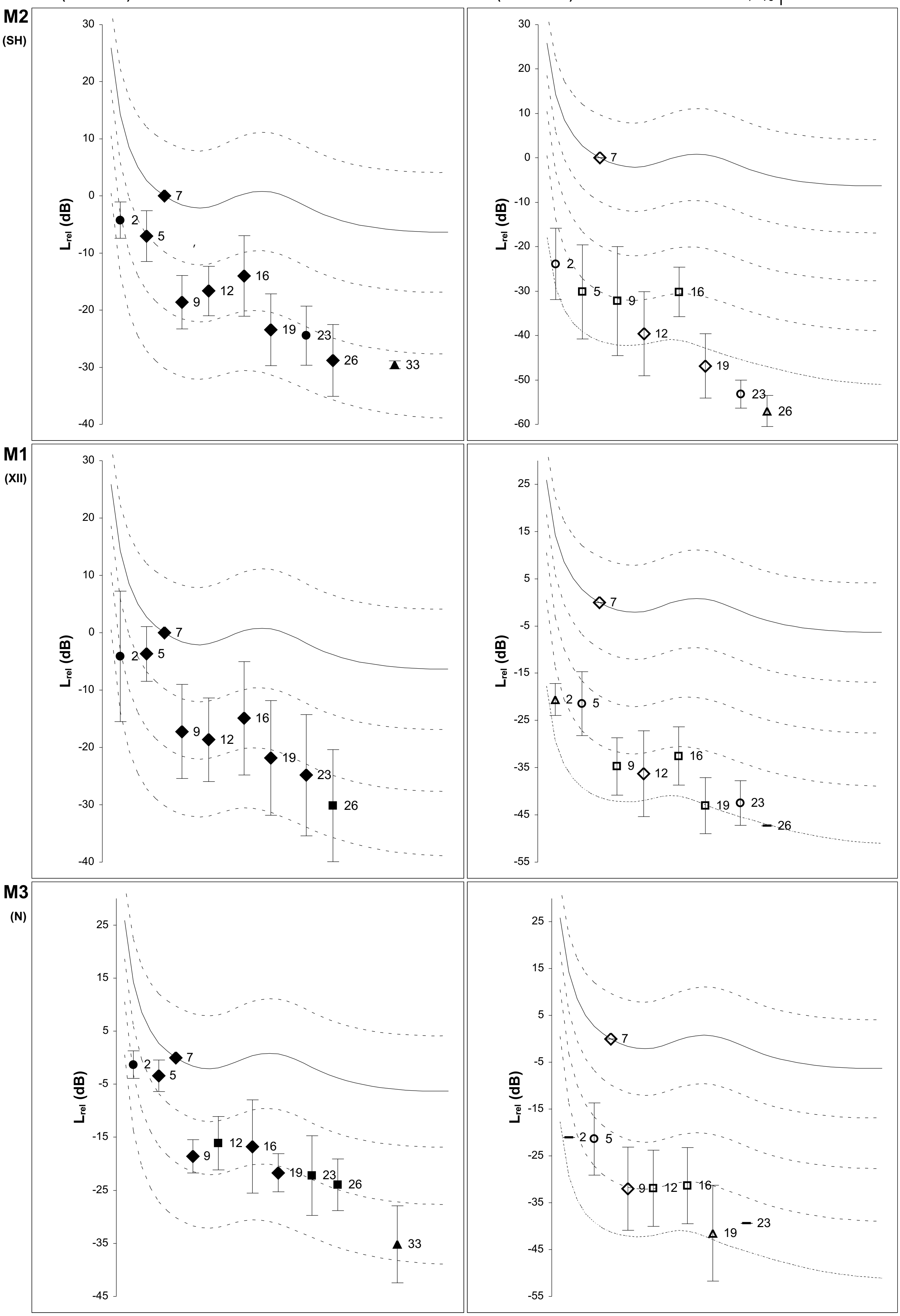
XIV.5

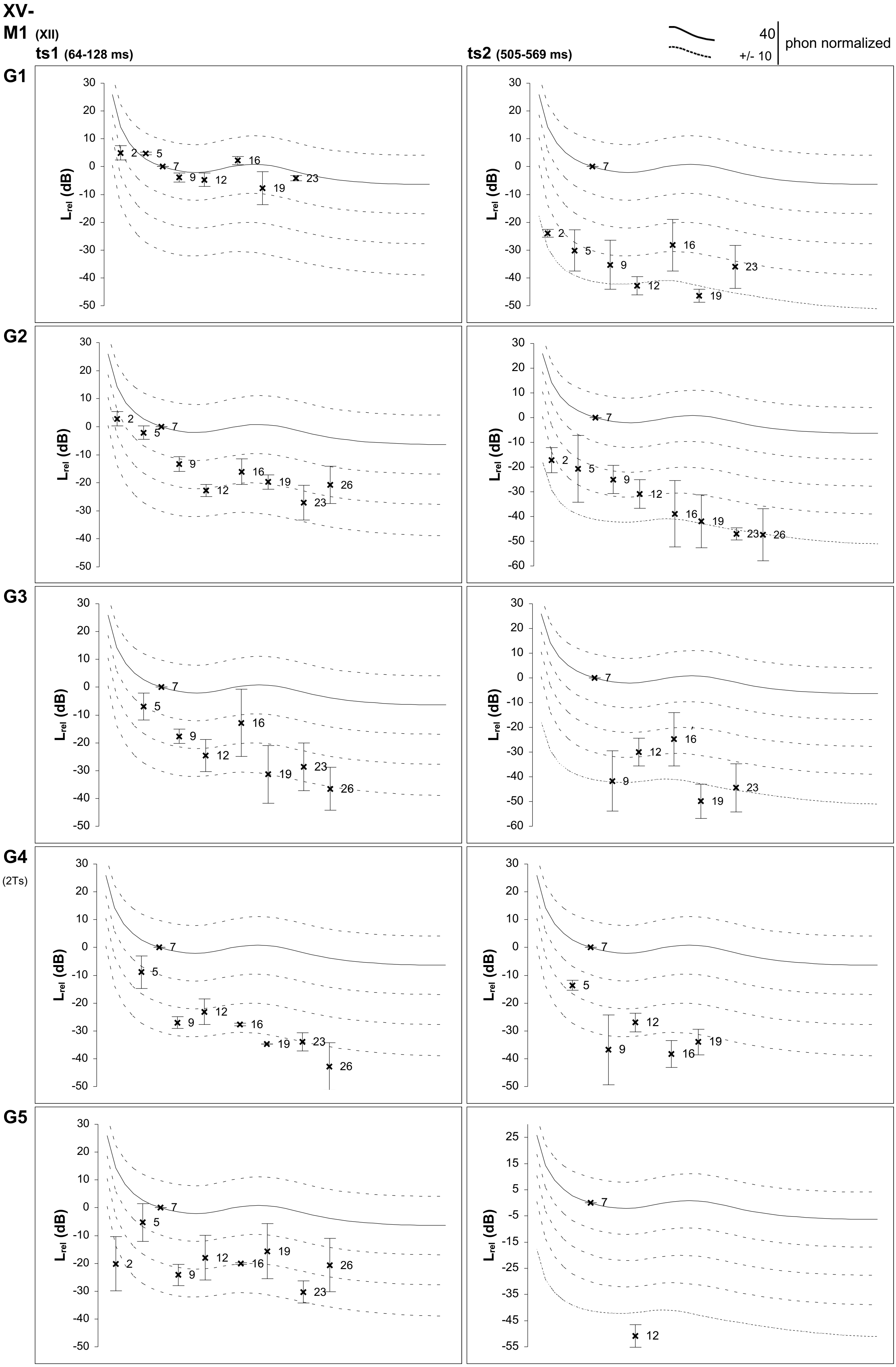
M3 (Neck)


ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
L_rel (dB)

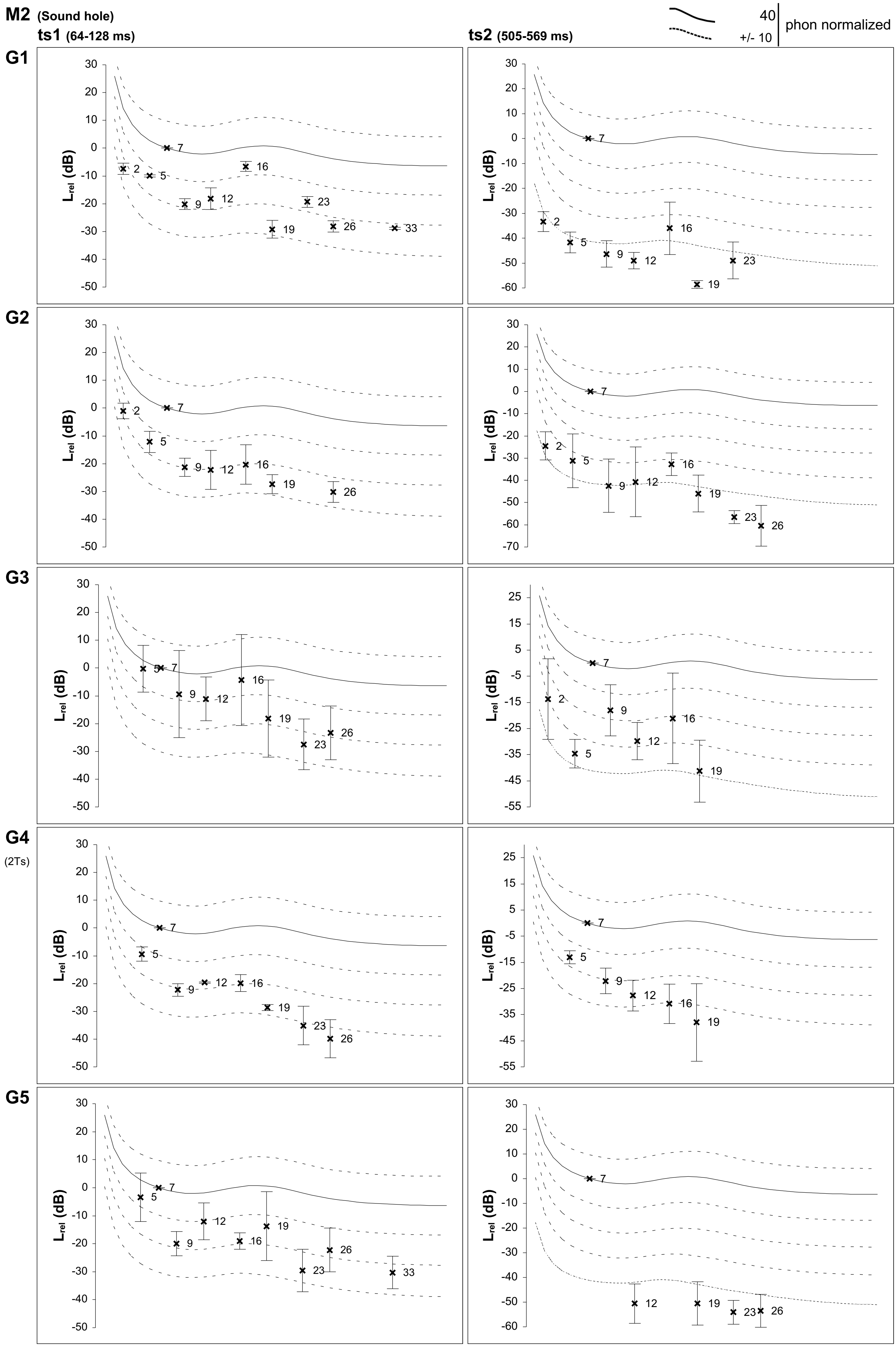
XV-
Sample (n=5)

partial detection: 5 Gs; 4Gs; 3 Gs; 2 Gs; 1 G — 40 / +/- 10 phon normalized




XV-
M1 (XII)
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
(2Ts)
G5
Lrel (dB)

XV-
M2 (Sound hole)



XV-

M3 (Neck)

ts1 (64-128 ms) **ts2** (505-569 ms)

40 | +/- 10 | phon normalized

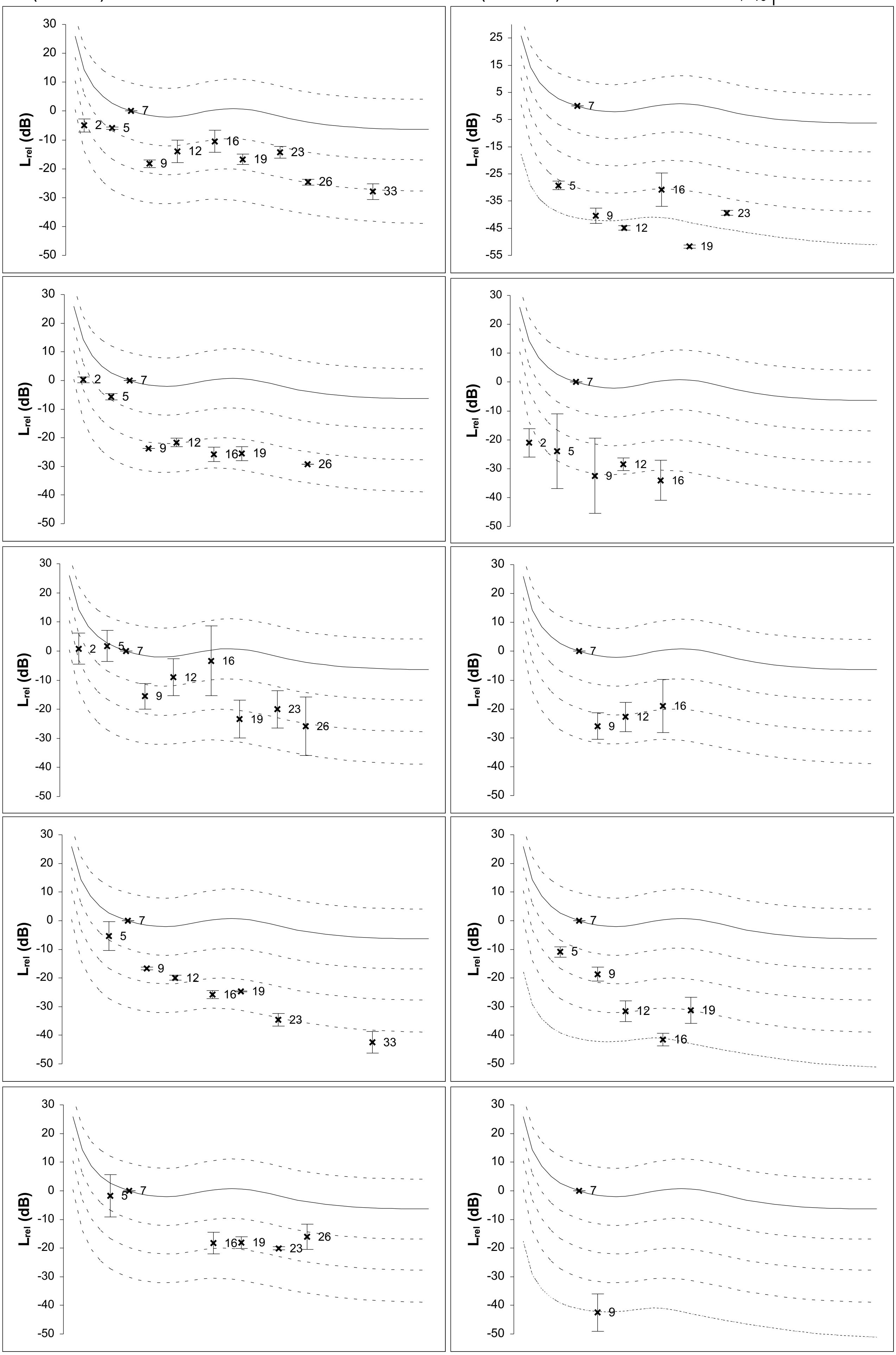
G1

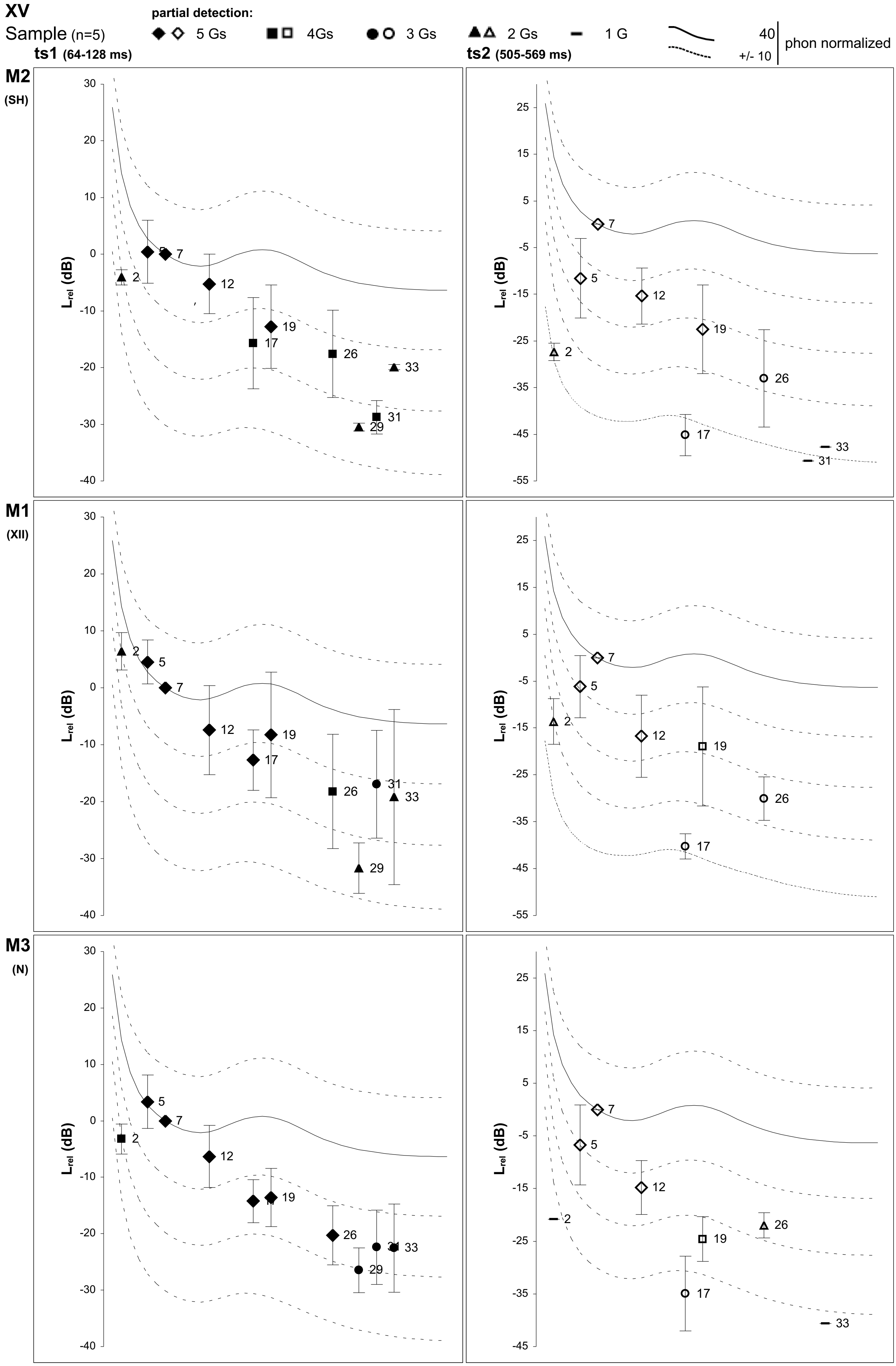
G2

G3

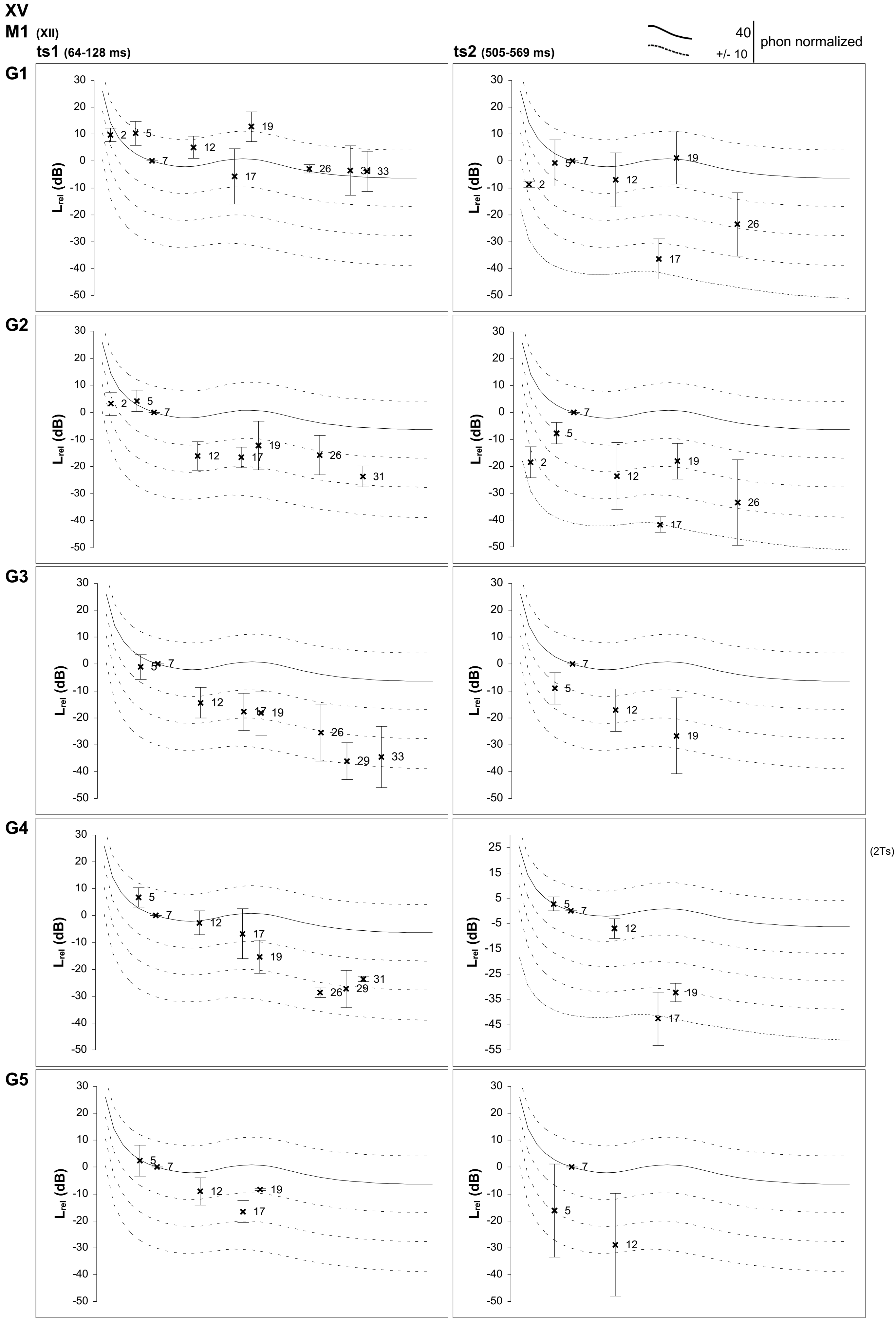
G4 (2Ts)

G5

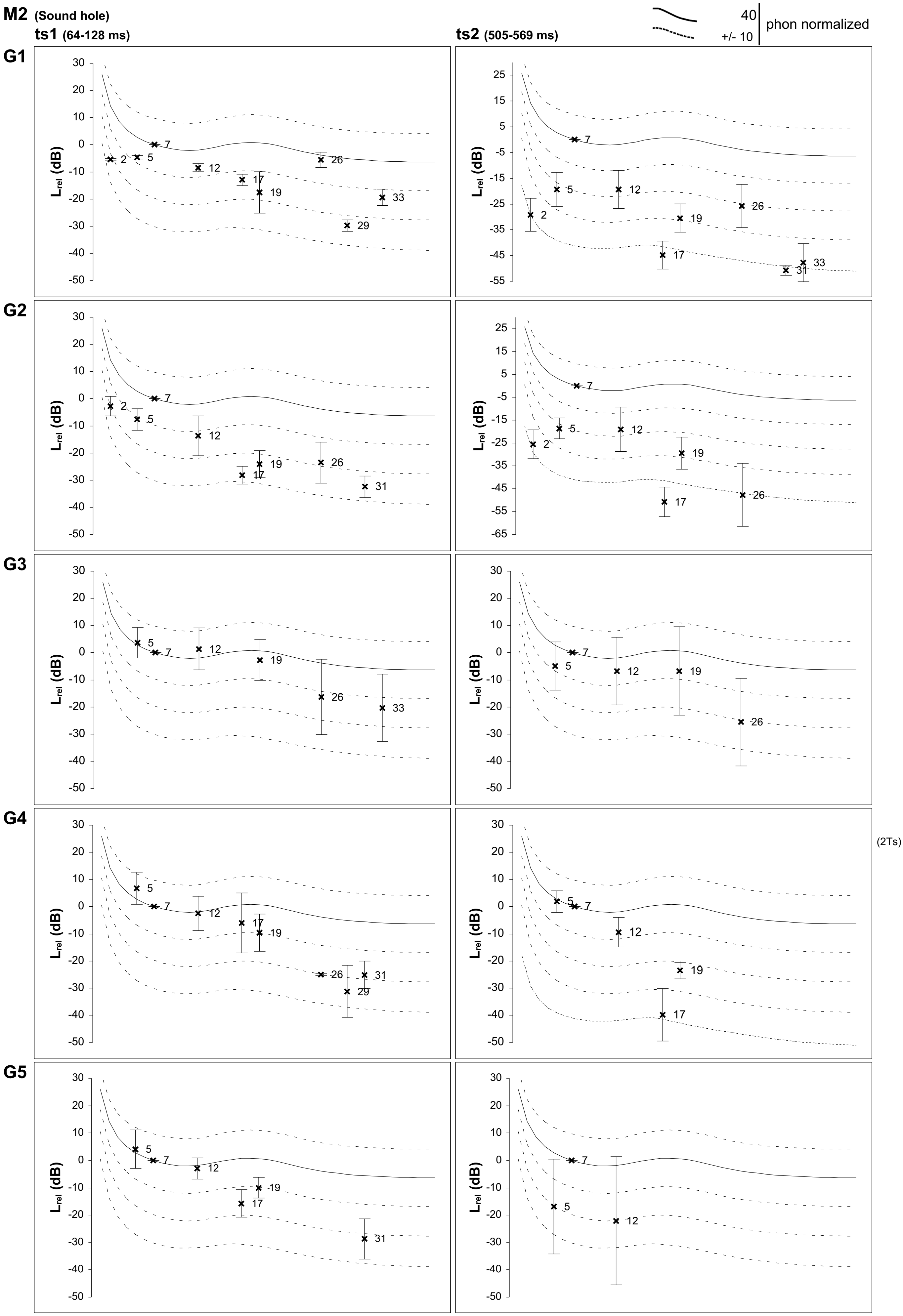




XV
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_{rel} (dB)


XV
M1 (XII)
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
Lrel (dB)
(2Ts)

XV

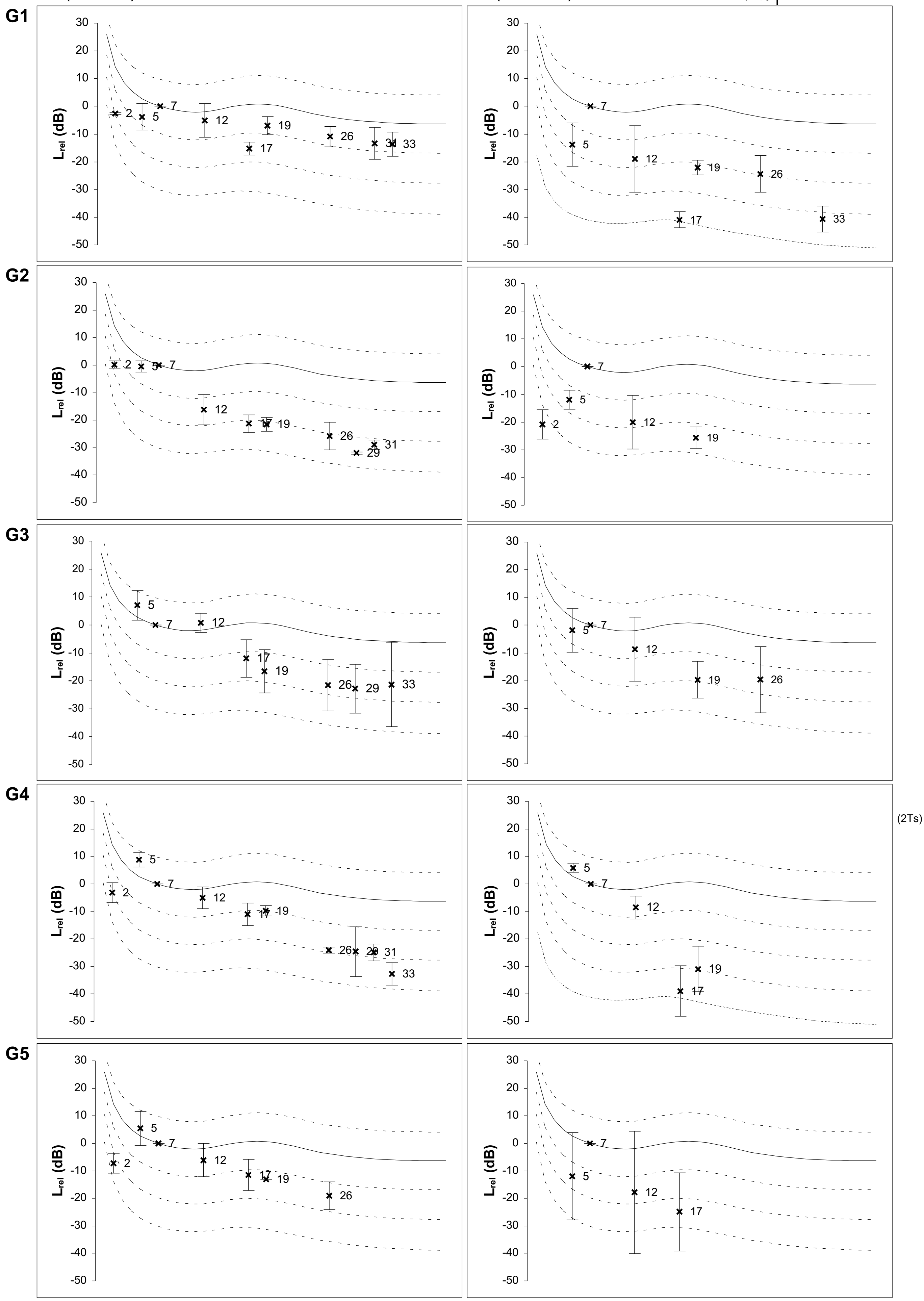

M2 (Sound hole)
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
(2Ts)
L_rel (dB)

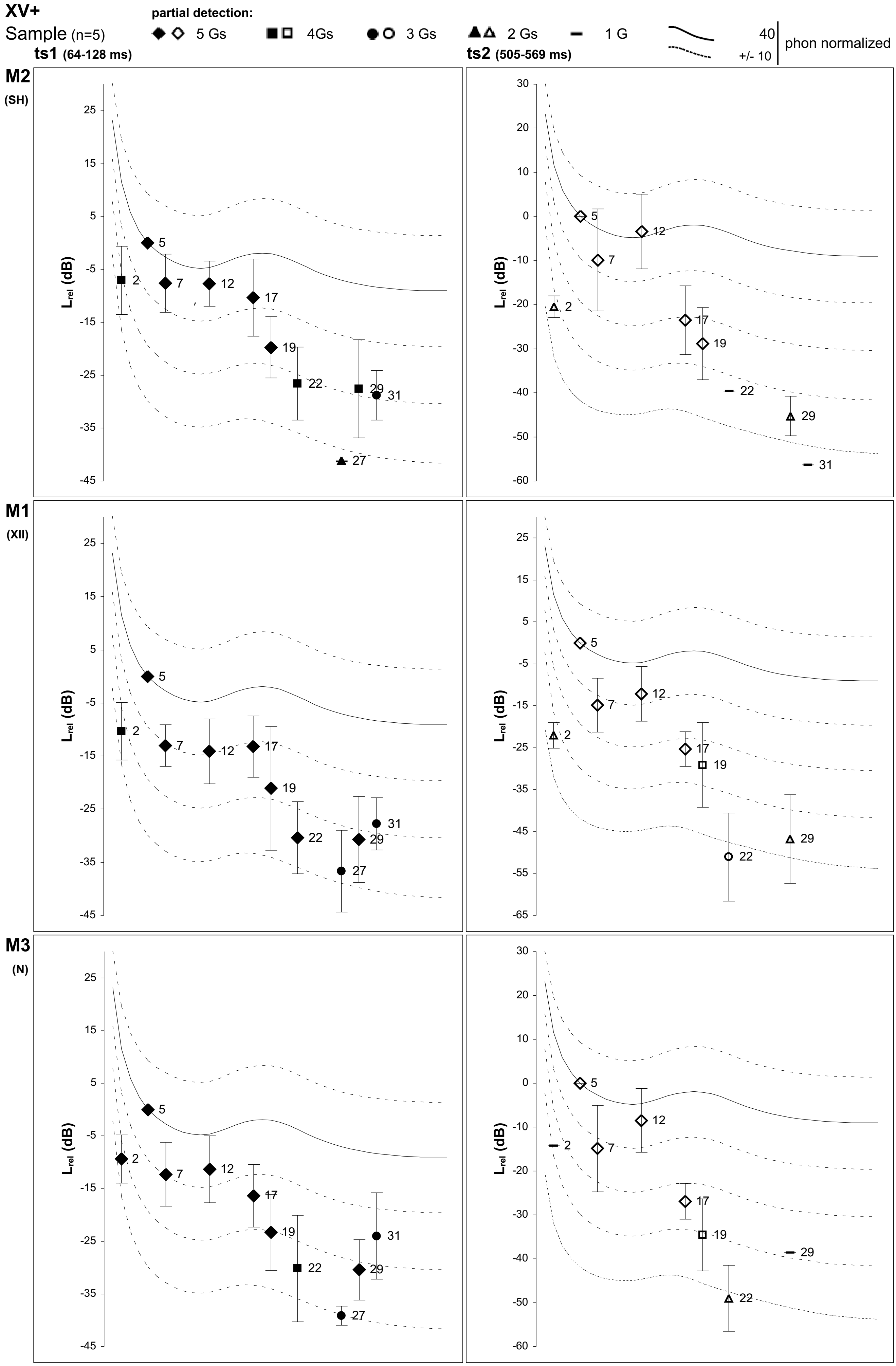
XV

M3 (Neck)

40 | phon normalized
+/- 10

ts1 (64-128 ms) **ts2** (505-569 ms)



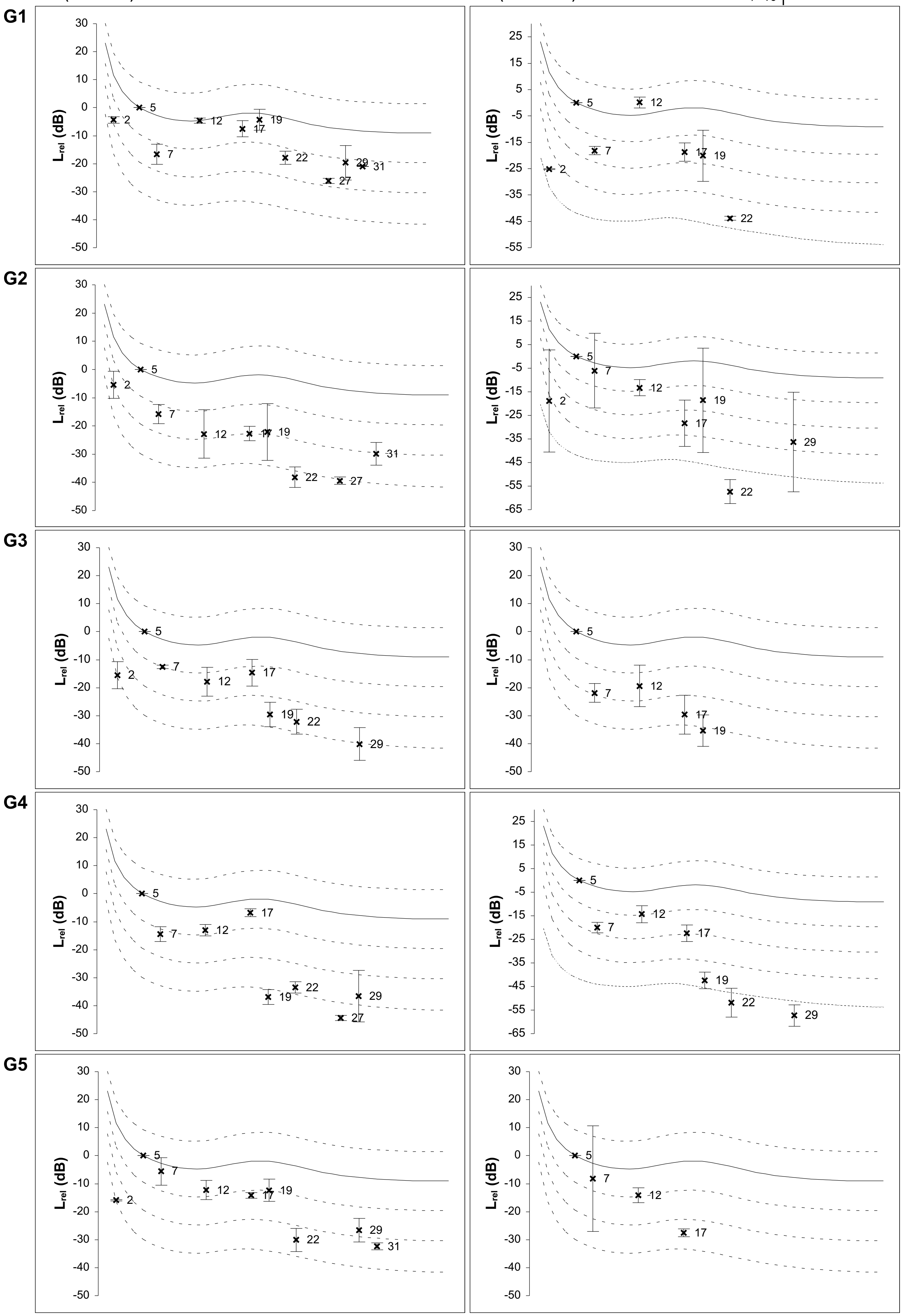

XV+
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L rel (dB)

XV+

M1 (XII)

ts1 (64-128 ms) **ts2** (505-569 ms)

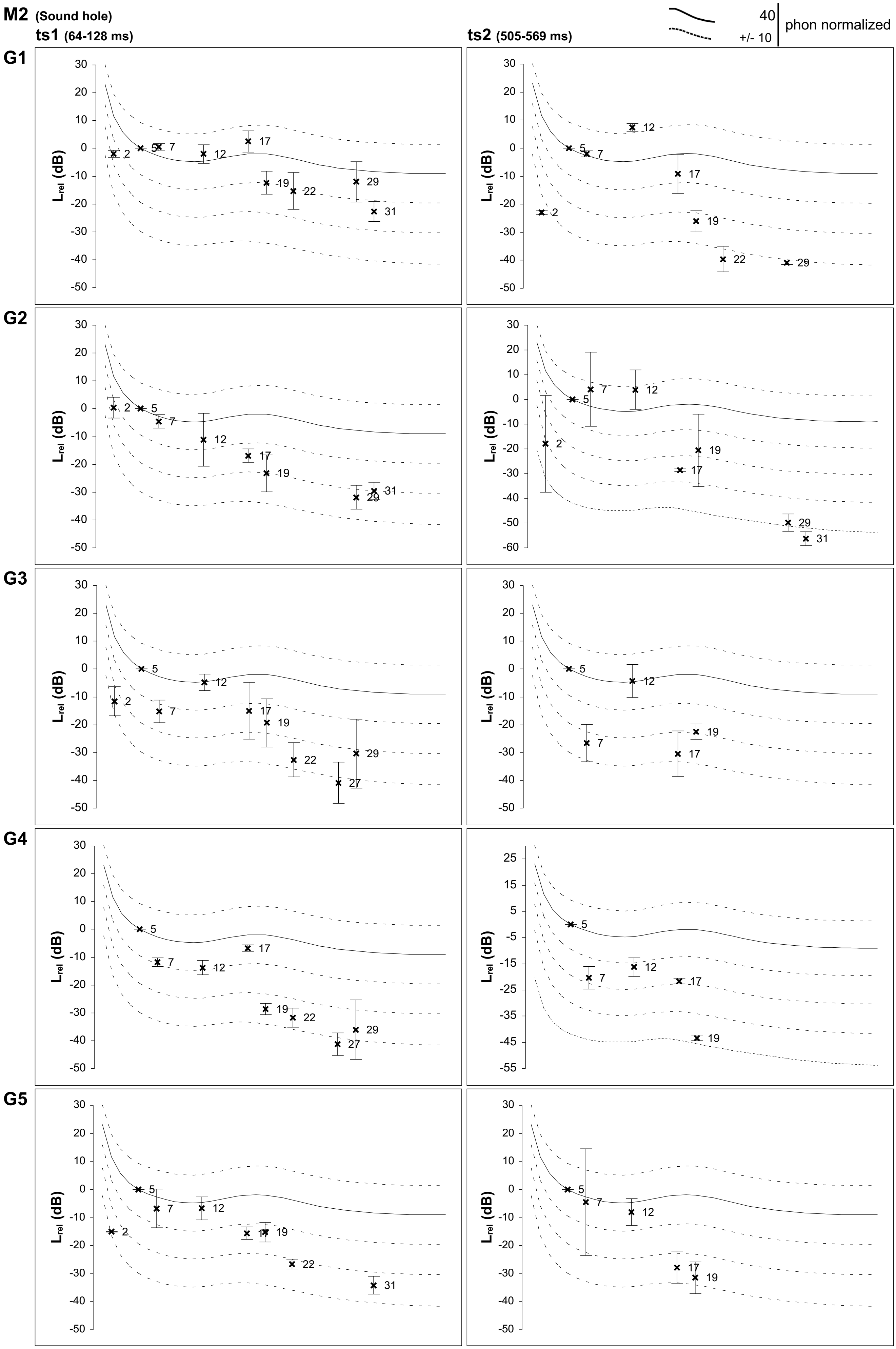
40 / +/- 10 phon normalized



XV+

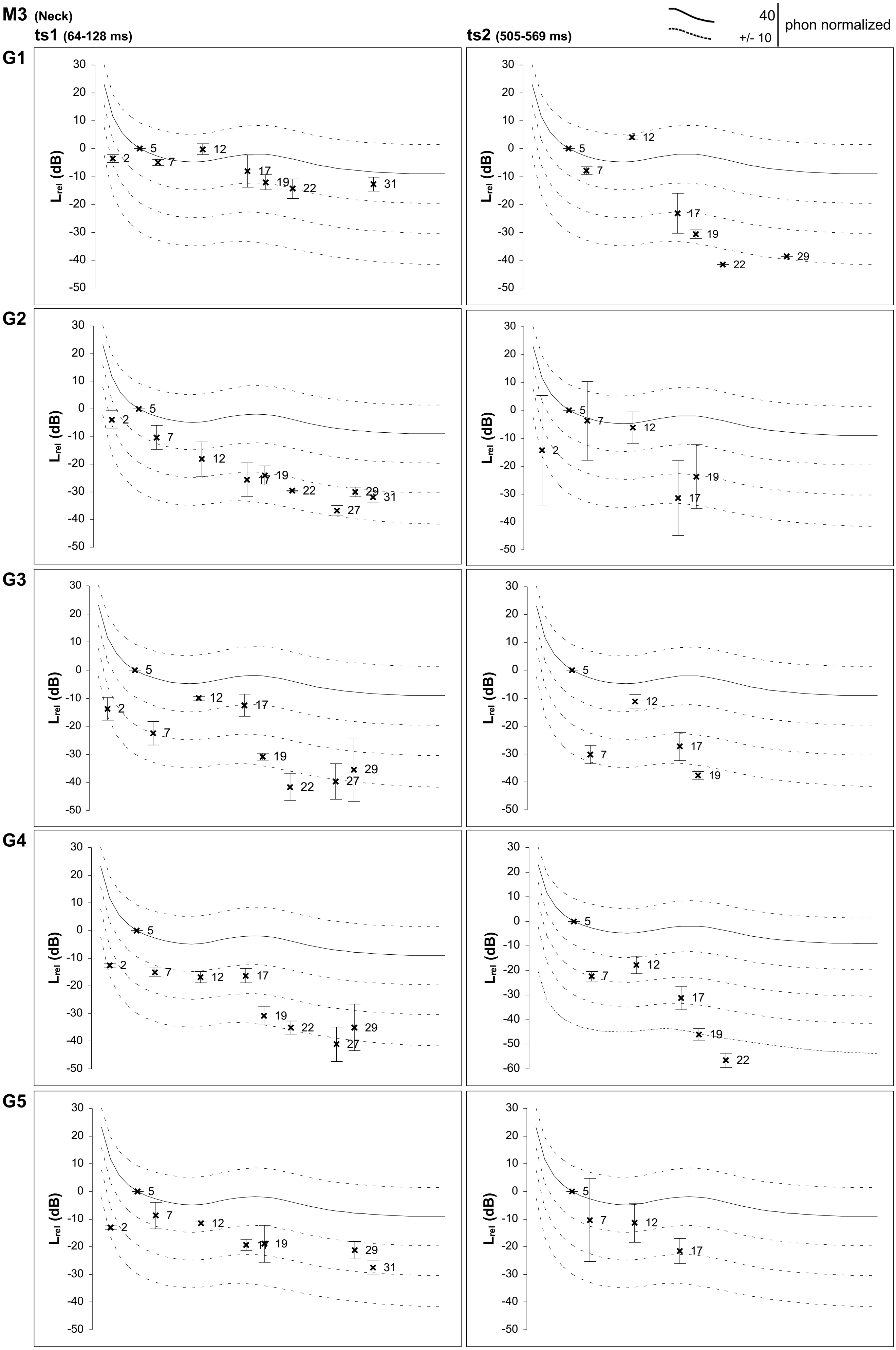
M2 (Sound hole)

ts1 (64-128 ms) **ts2** (505-569 ms)

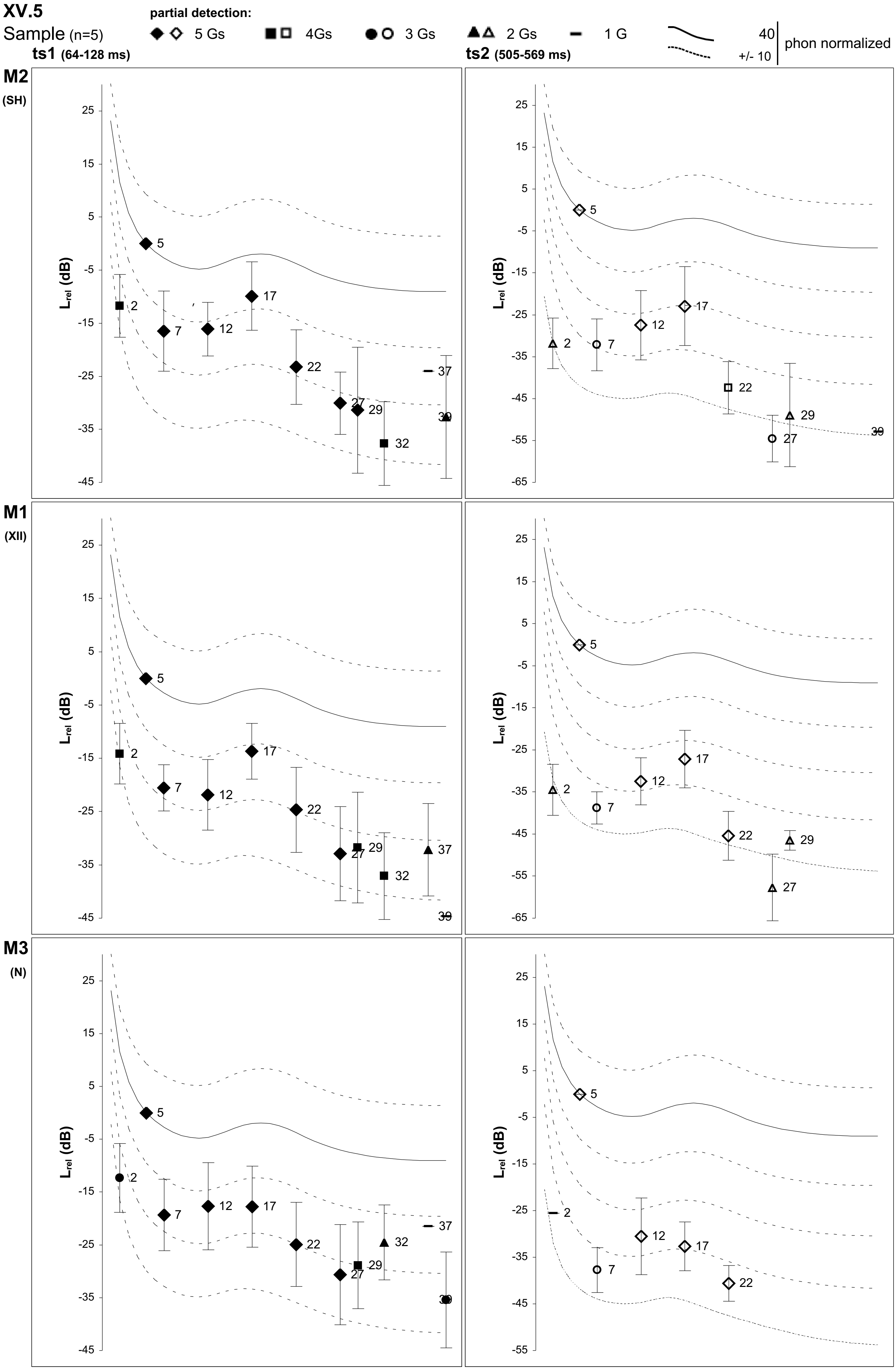


XV+

M3 (Neck)



ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
L_rel (dB)


XV.5
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_{rel} (dB)

XV.5

M1 (XII)

ts1 (64-128 ms) **ts2** (505-569 ms)

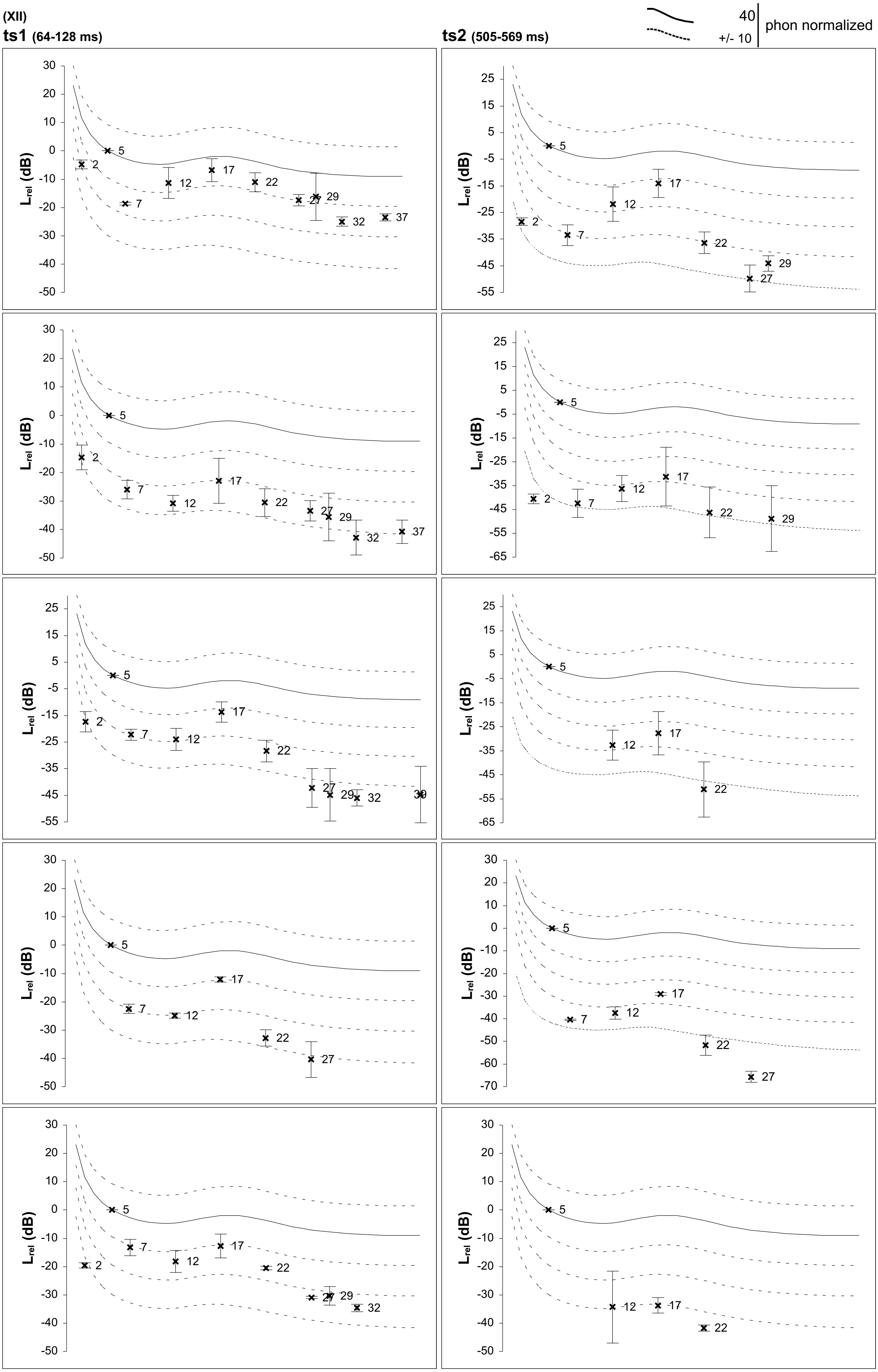
G1

G2

G3

G4

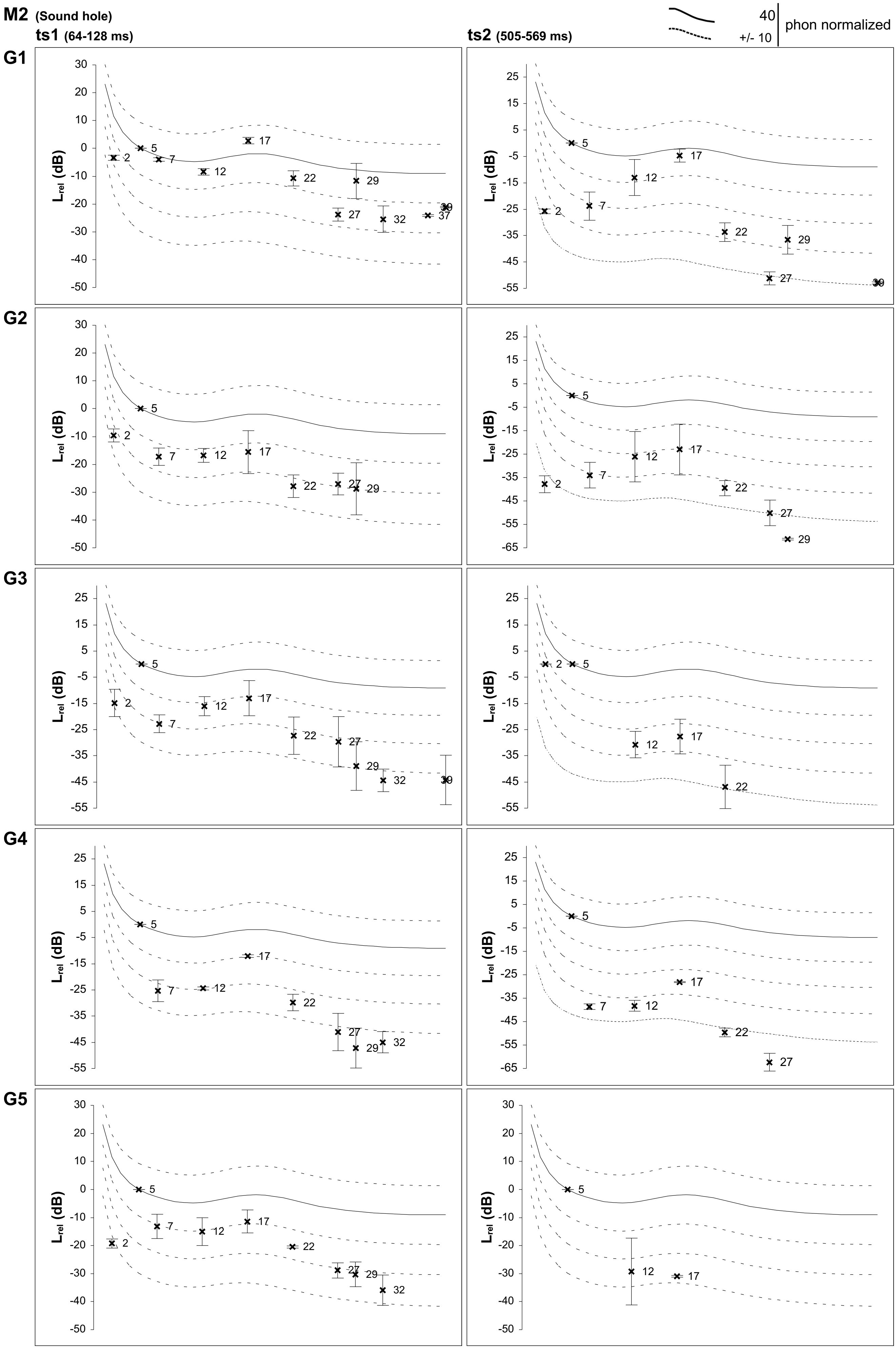
G5



XV.5

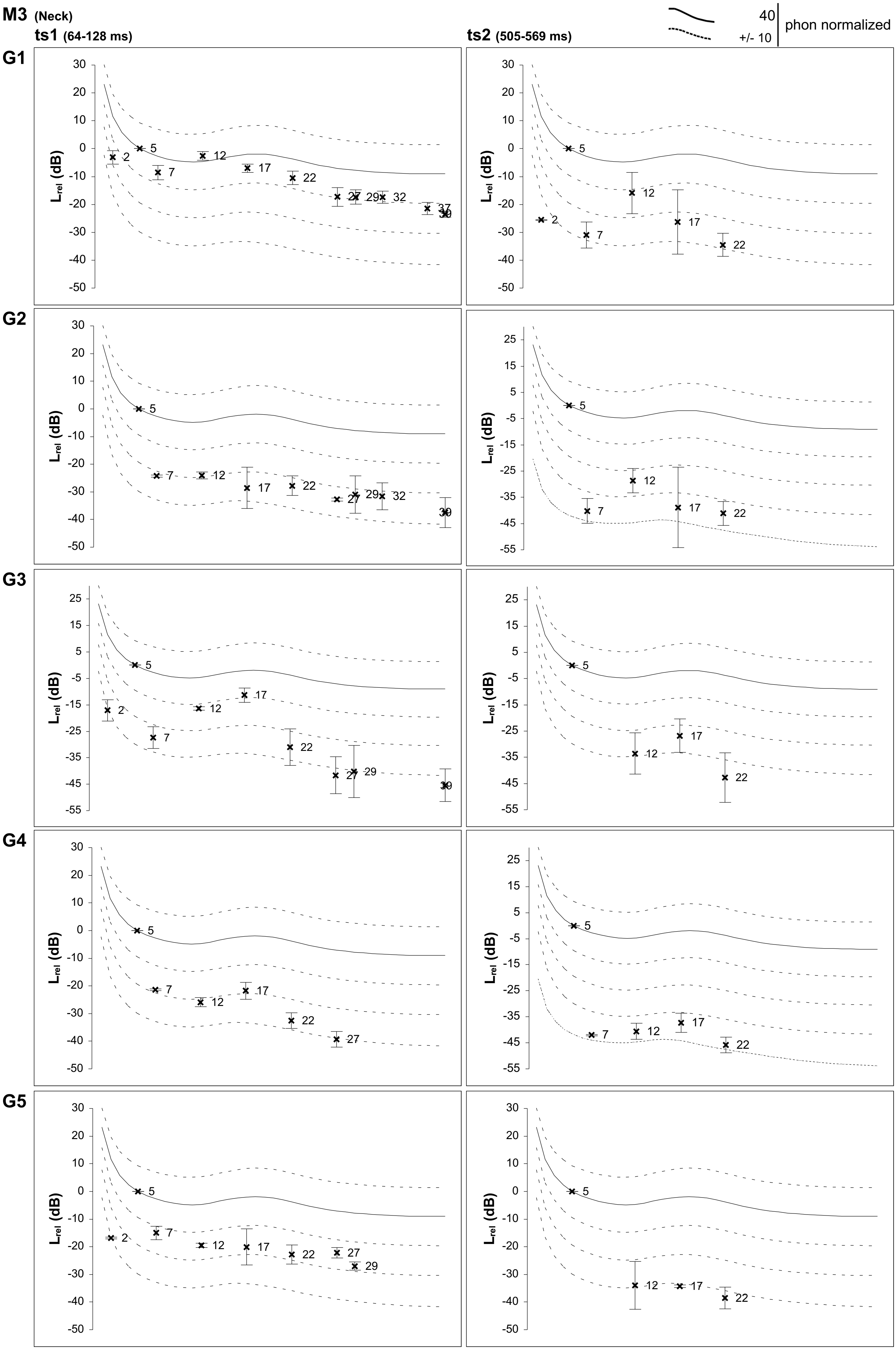
M2 (Sound hole)

ts1 (64-128 ms) **ts2** (505-569 ms)

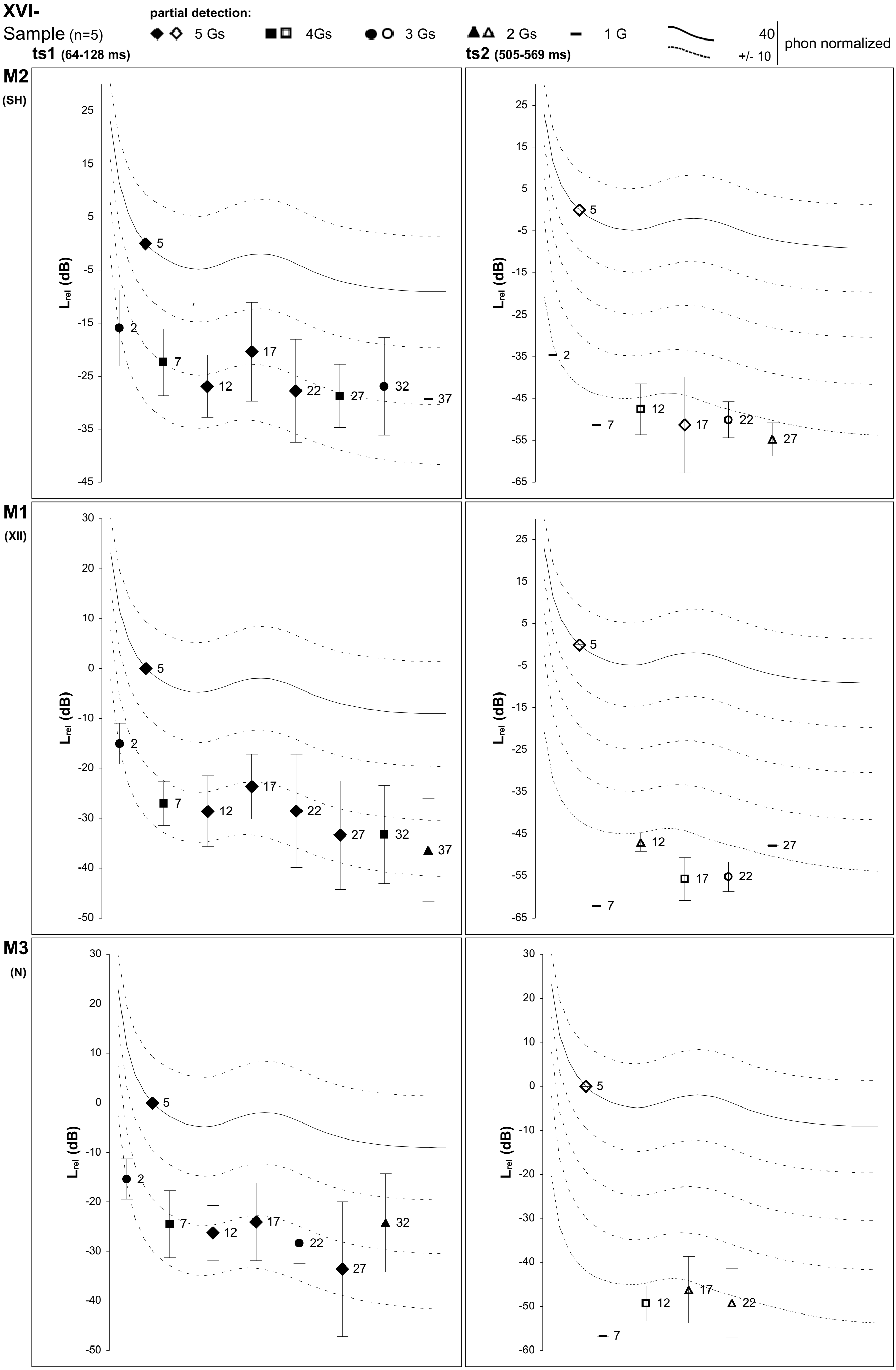


XV.5

M3 (Neck)

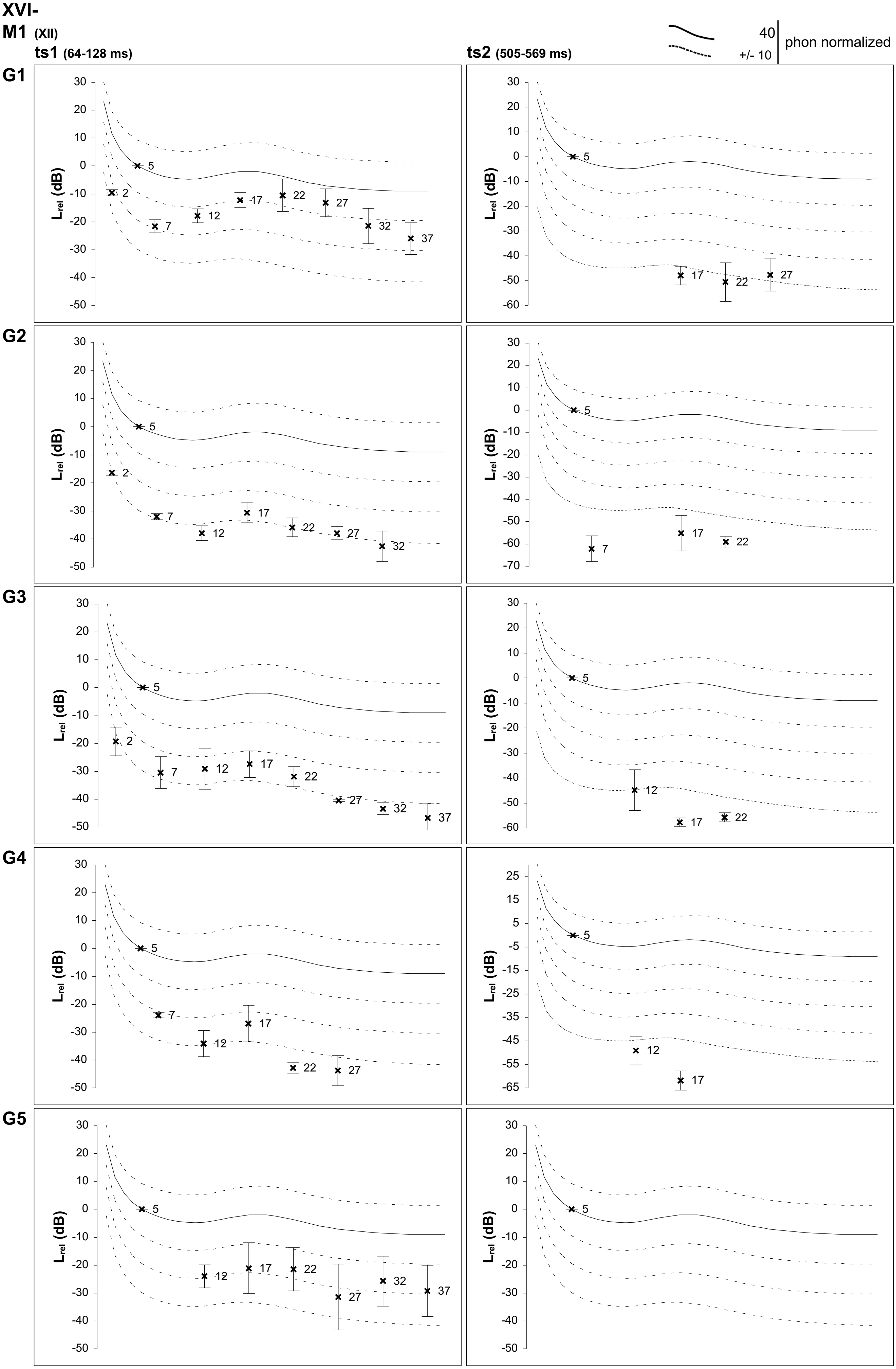


ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
Lrel (dB)



XVI-
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L$_{rel}$ (dB)

XVI-
M1 (XII)

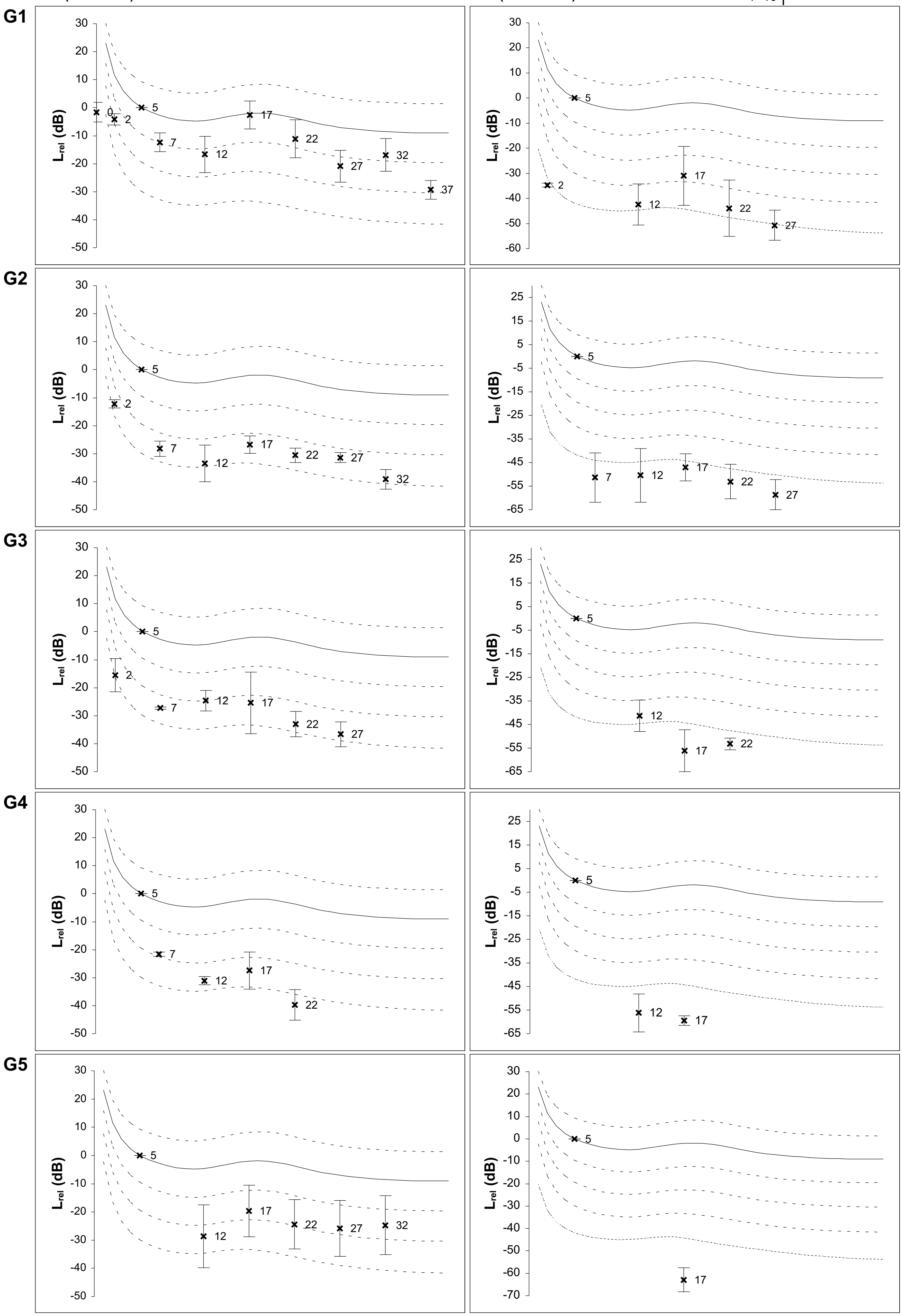

ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
Lrel (dB)

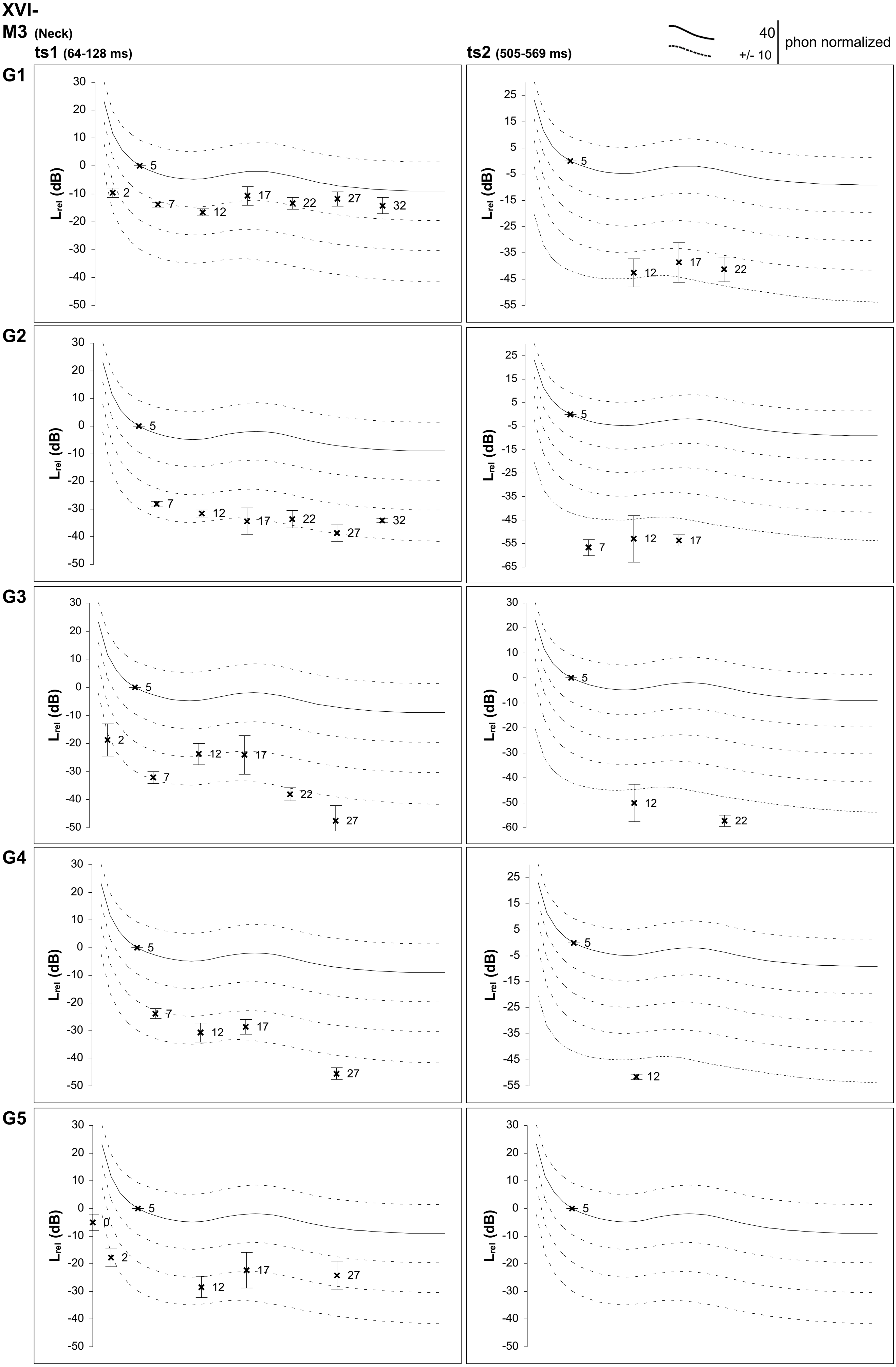
XVI-

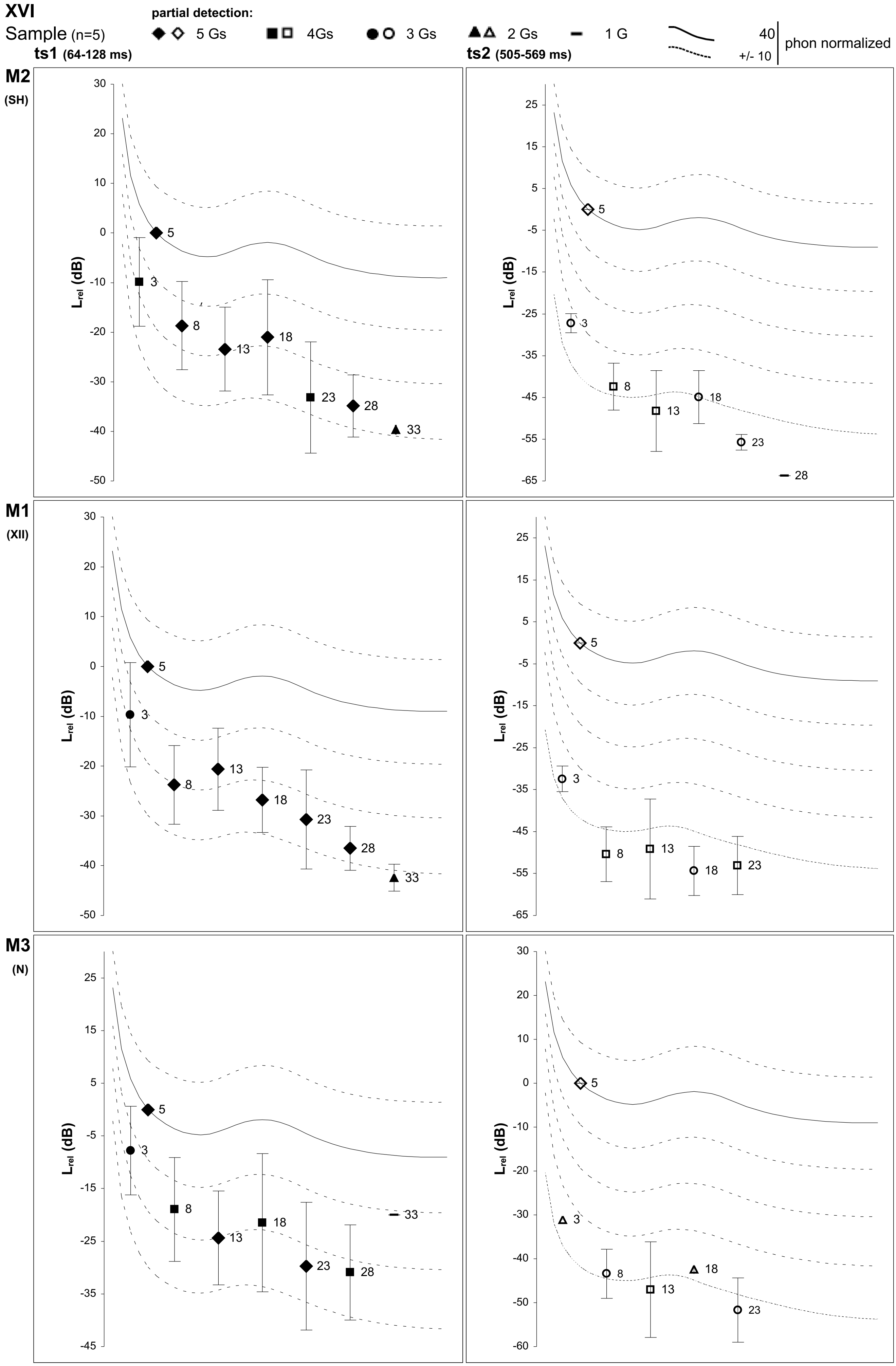
M2 **(Sound hole)**

ts1 **(64-128 ms)** **ts2** **(505-569 ms)**

40 | phon normalized
+/- 10



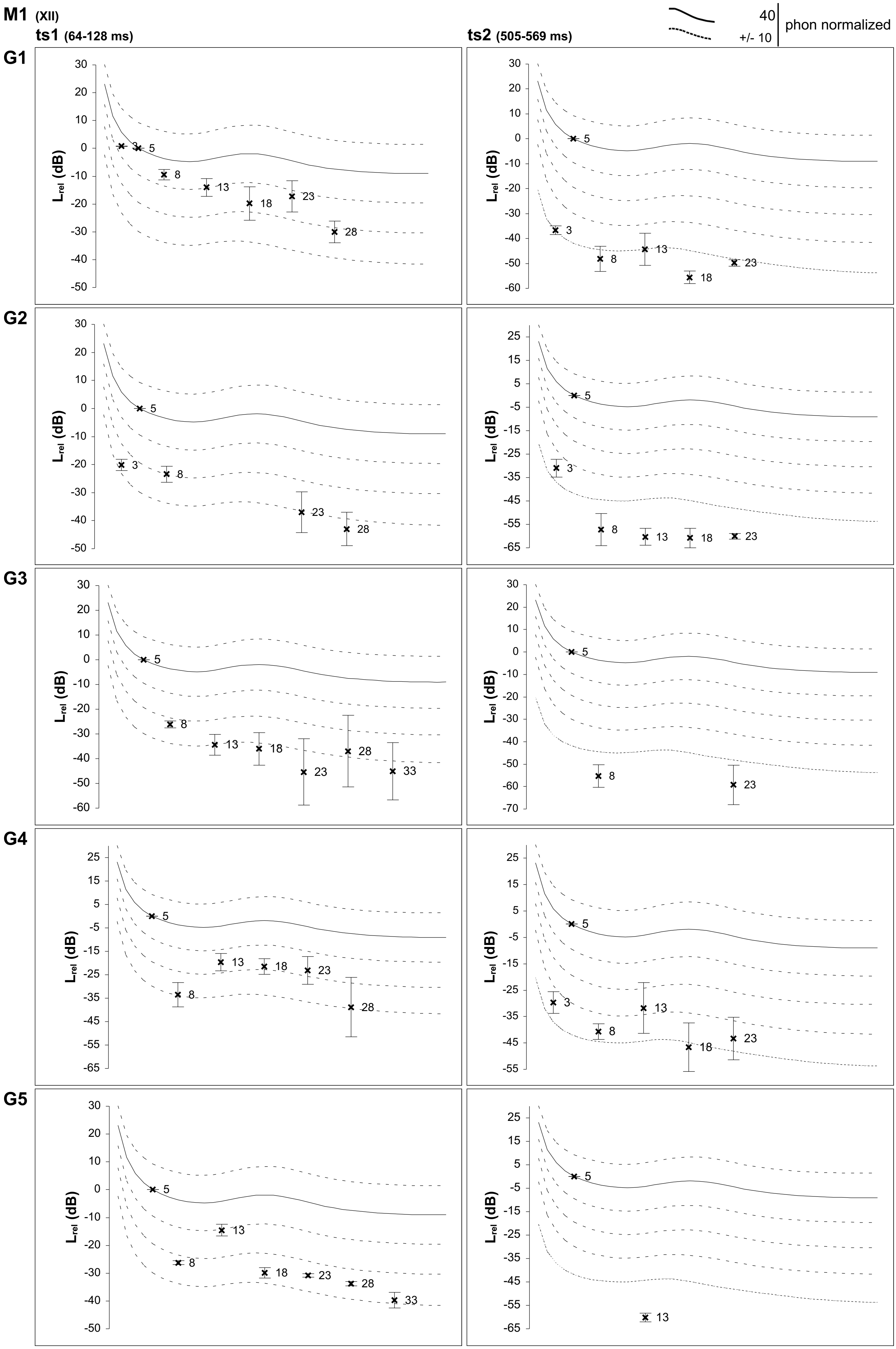

XVI-
M3 (Neck)
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
Lrel (dB)


XVI
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_rel (dB)

XVI

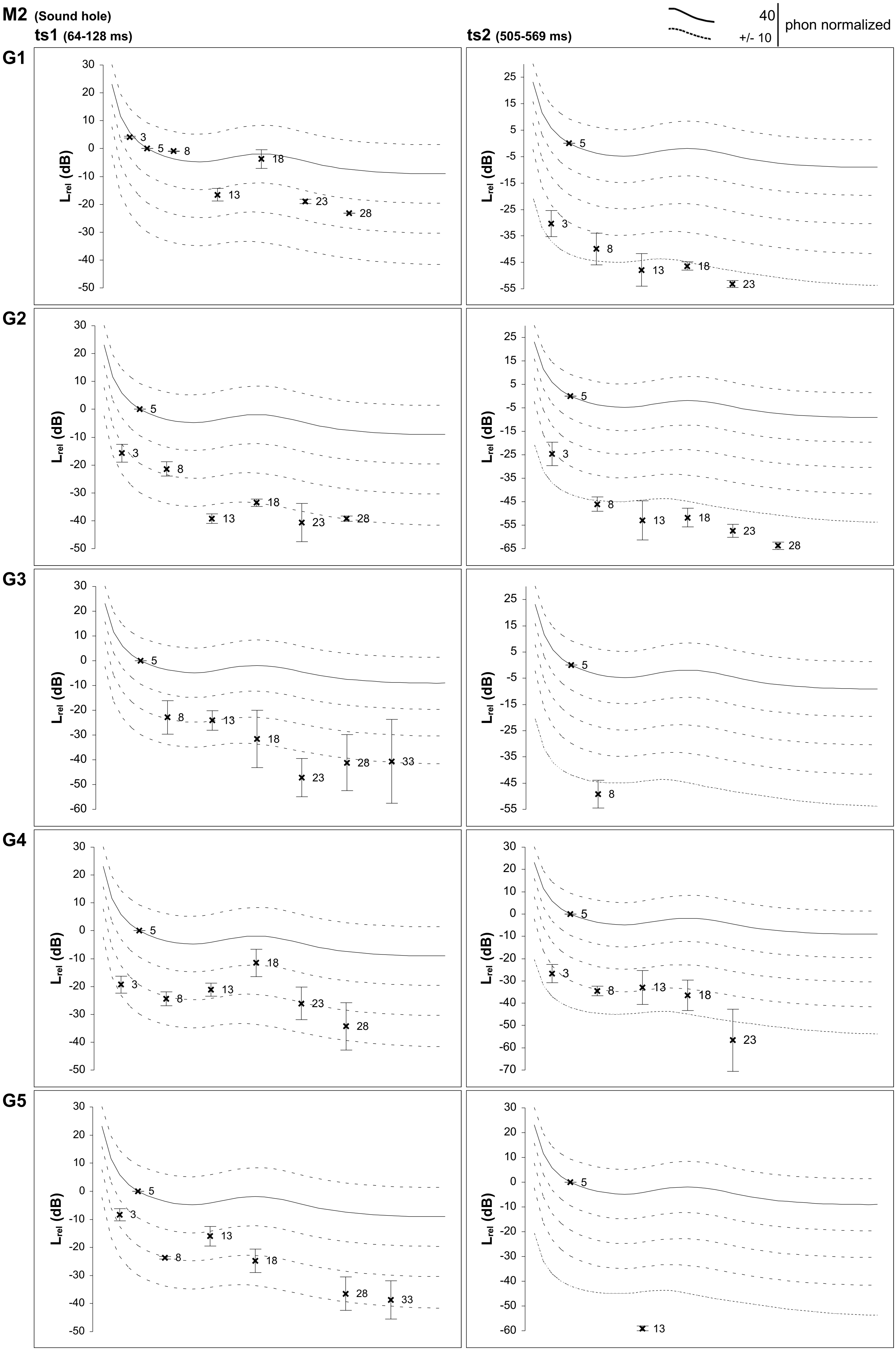
M1 (XII)

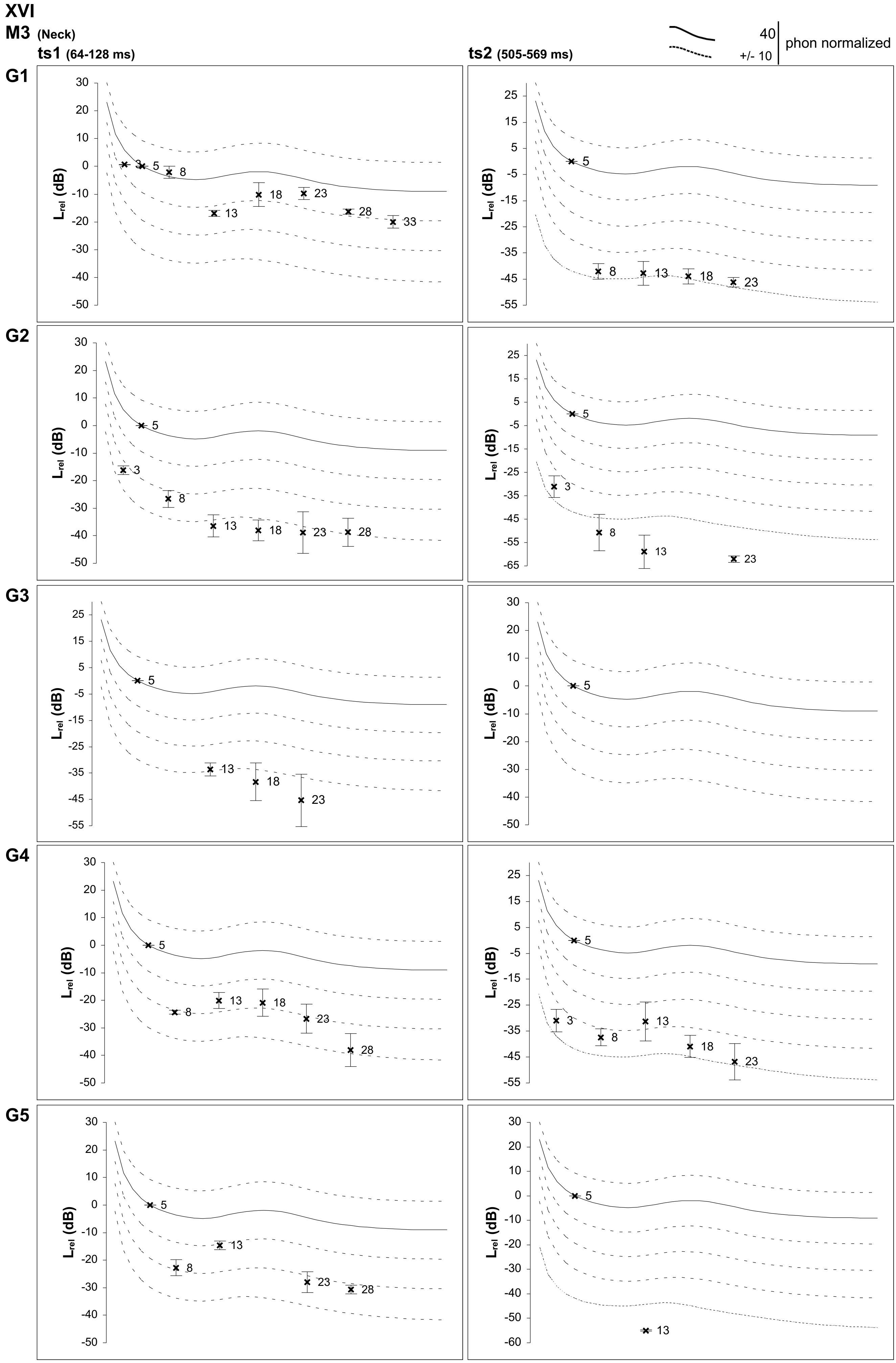
ts1 (64-128 ms) **ts2** (505-569 ms)

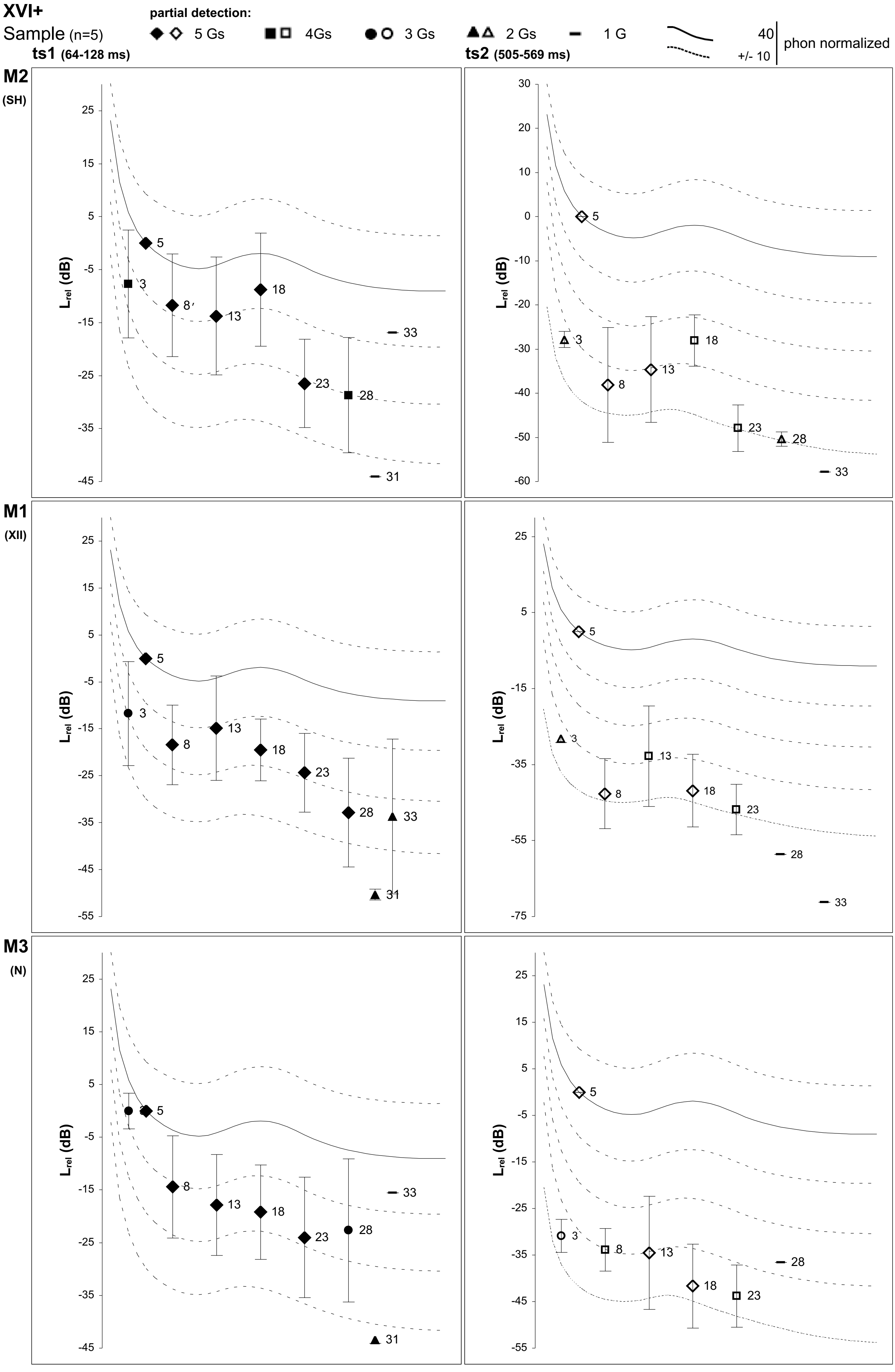


XVI

M2 (Sound hole)



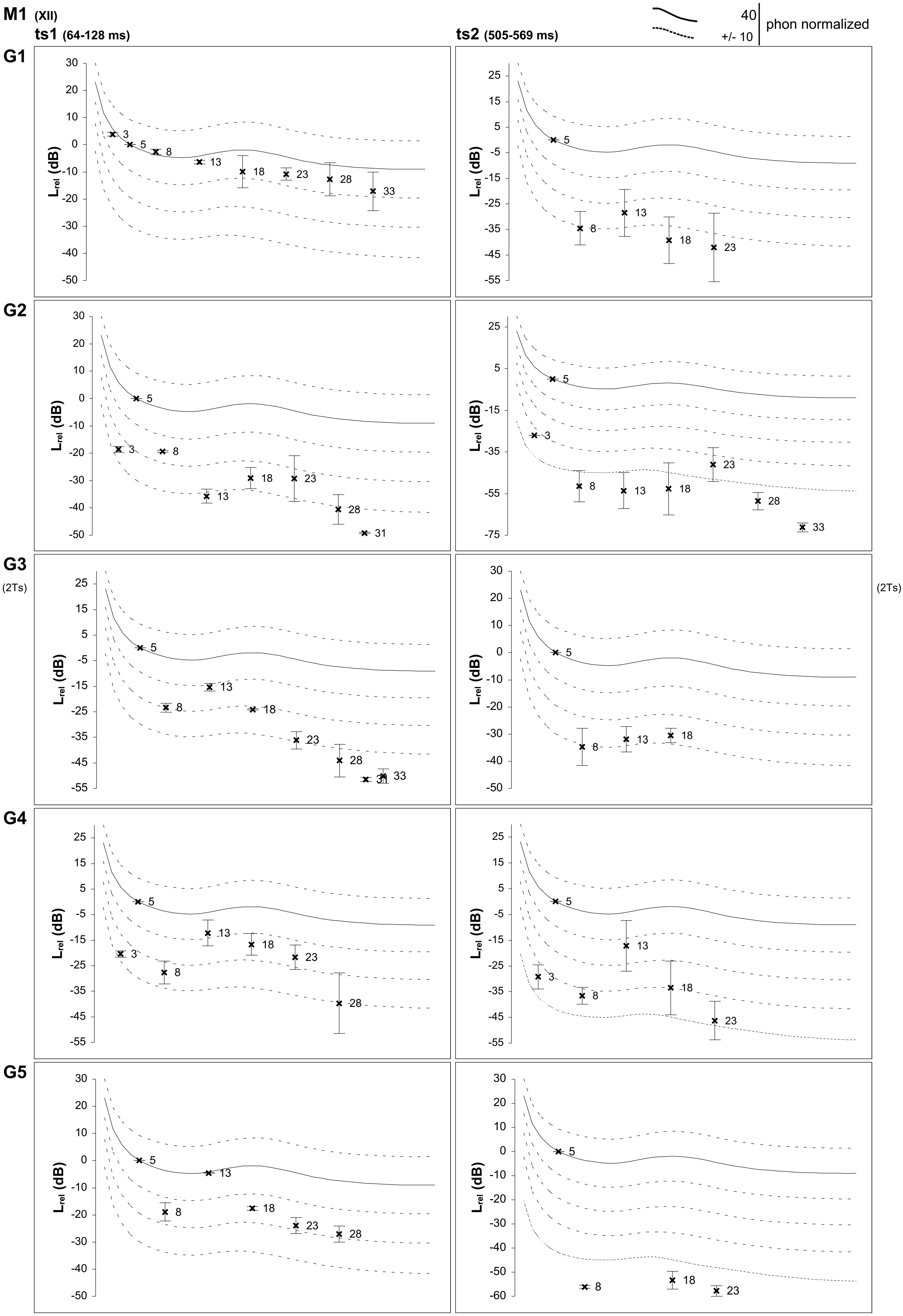

XVI
M3 (Neck)
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
Lrel (dB)


XVI+
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_{rel} (dB)

XVI+

M1 (XII)

ts1 (64-128 ms) **ts2** (505-569 ms)



XVI+

M2 (Sound hole)

ts1 (64-128 ms) **ts2** (505-569 ms)

40 | +/- 10 phon normalized

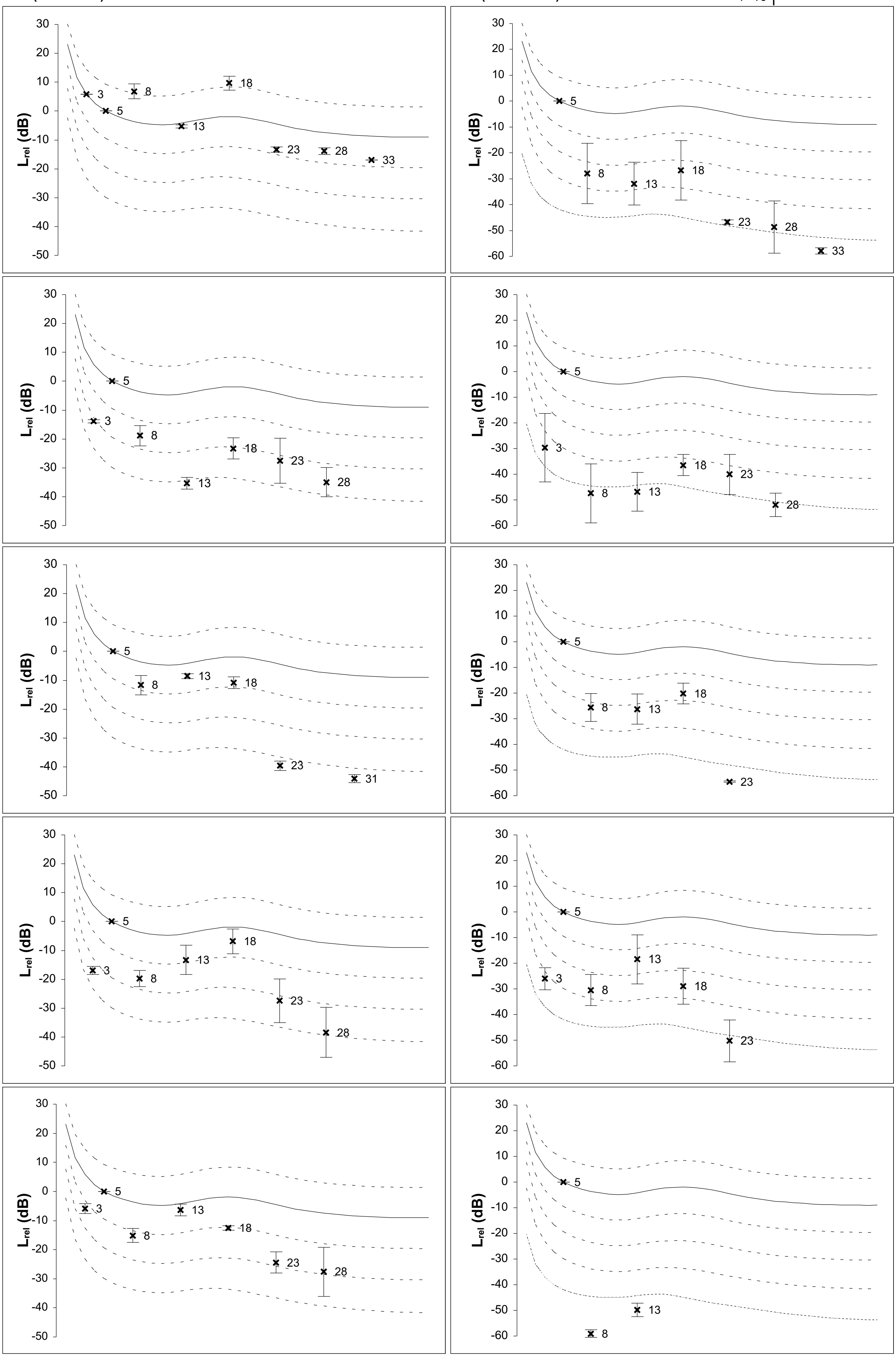
G1 (2Ts)

G2

G3 (2Ts) (2Ts)

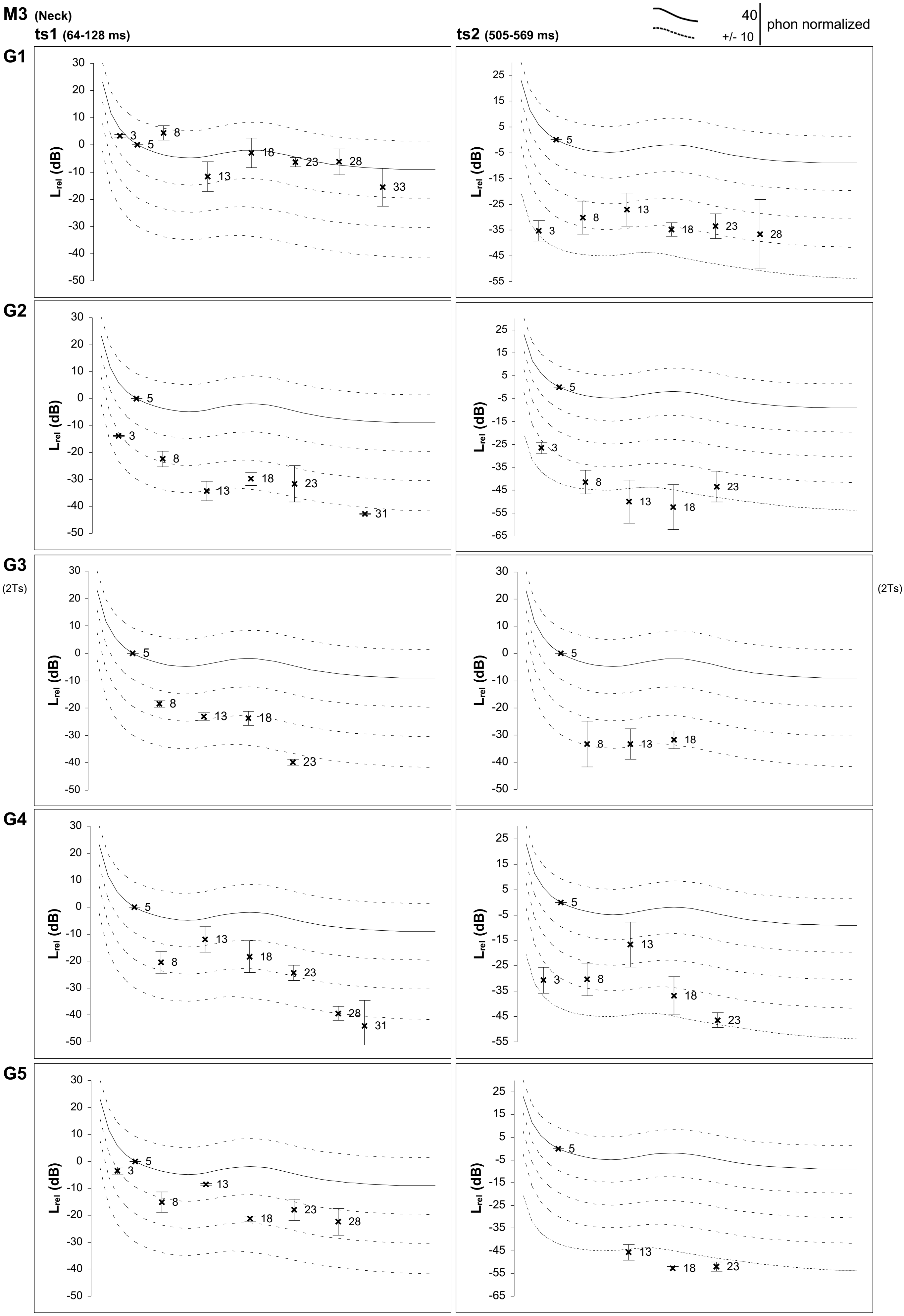
G4

G5

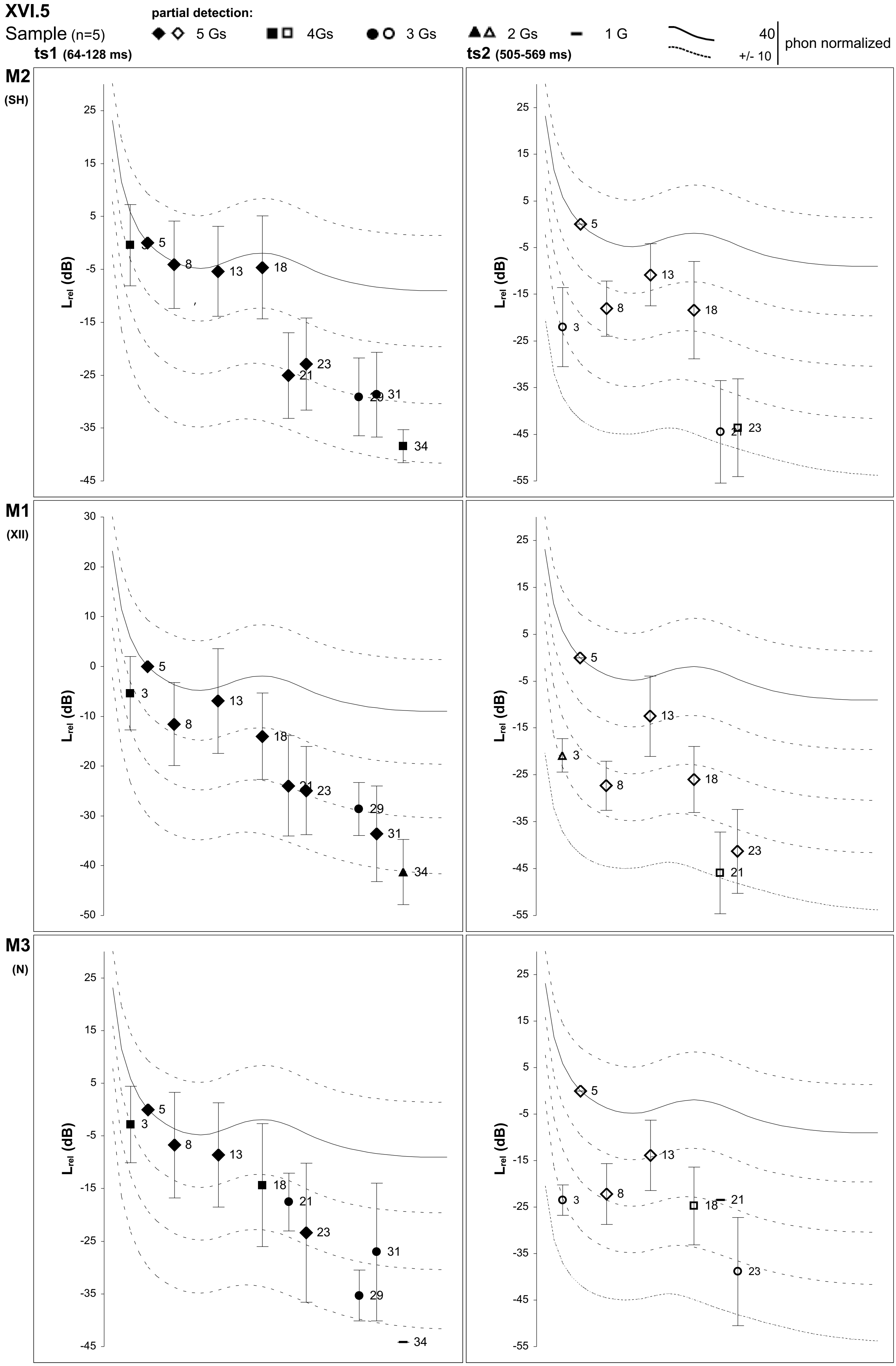


XVI+

M3 (Neck)

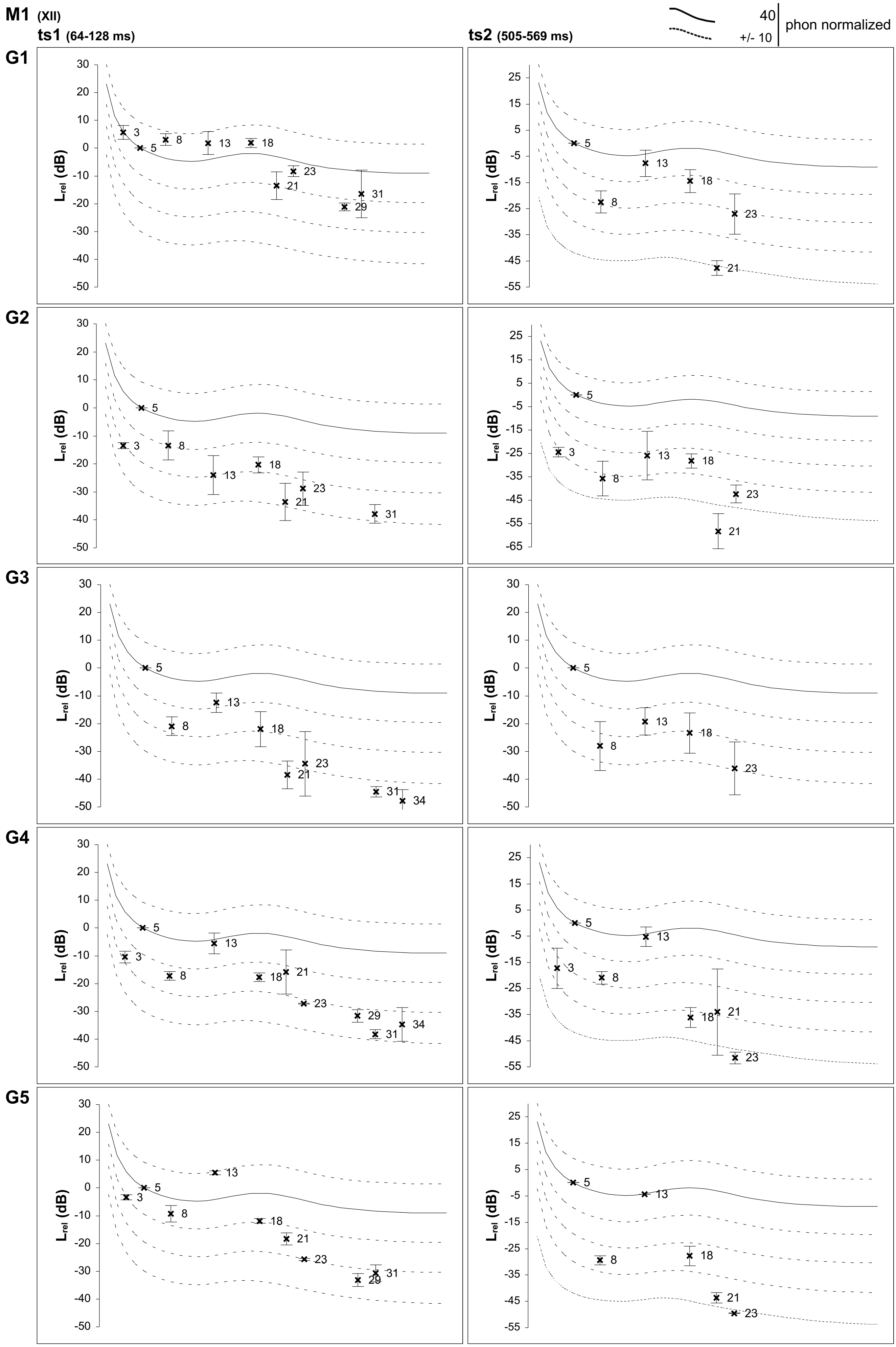


40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
G1
G2
G3
(2Ts)
G4
G5
Lrel (dB)


XVI.5
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
Lrel (dB)

XVI.5

M1 (XII)

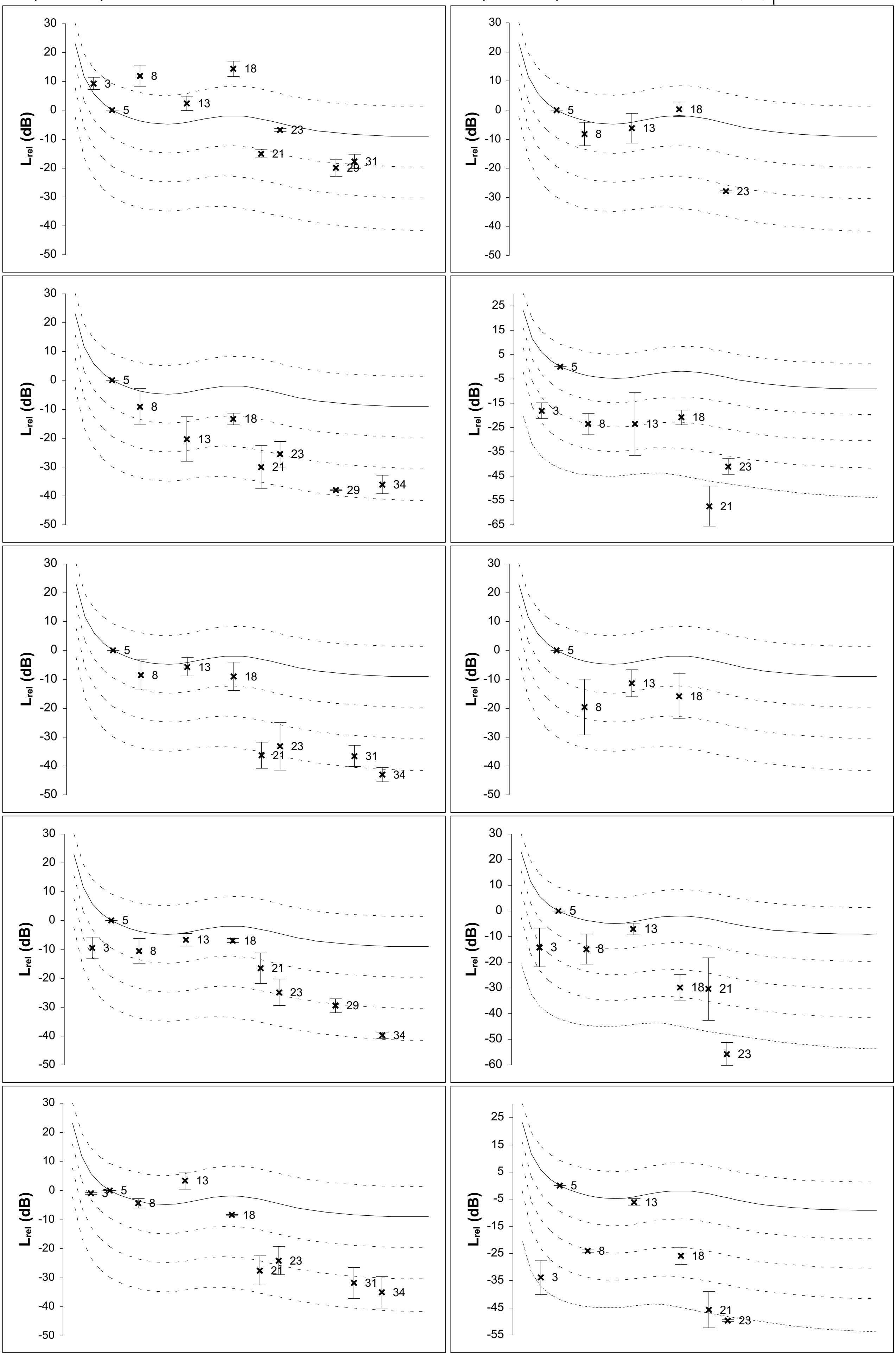

ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
L_{rel} (dB)

XVI.5

M2 (Sound hole)

ts1 (64-128 ms) | **ts2** (505-569 ms)

G1
G2
G3
G4
G5



XVI.5

M3 (Neck)

40 | phon normalized
+/- 10 |

ts1 (64-128 ms) **ts2** (505-569 ms)

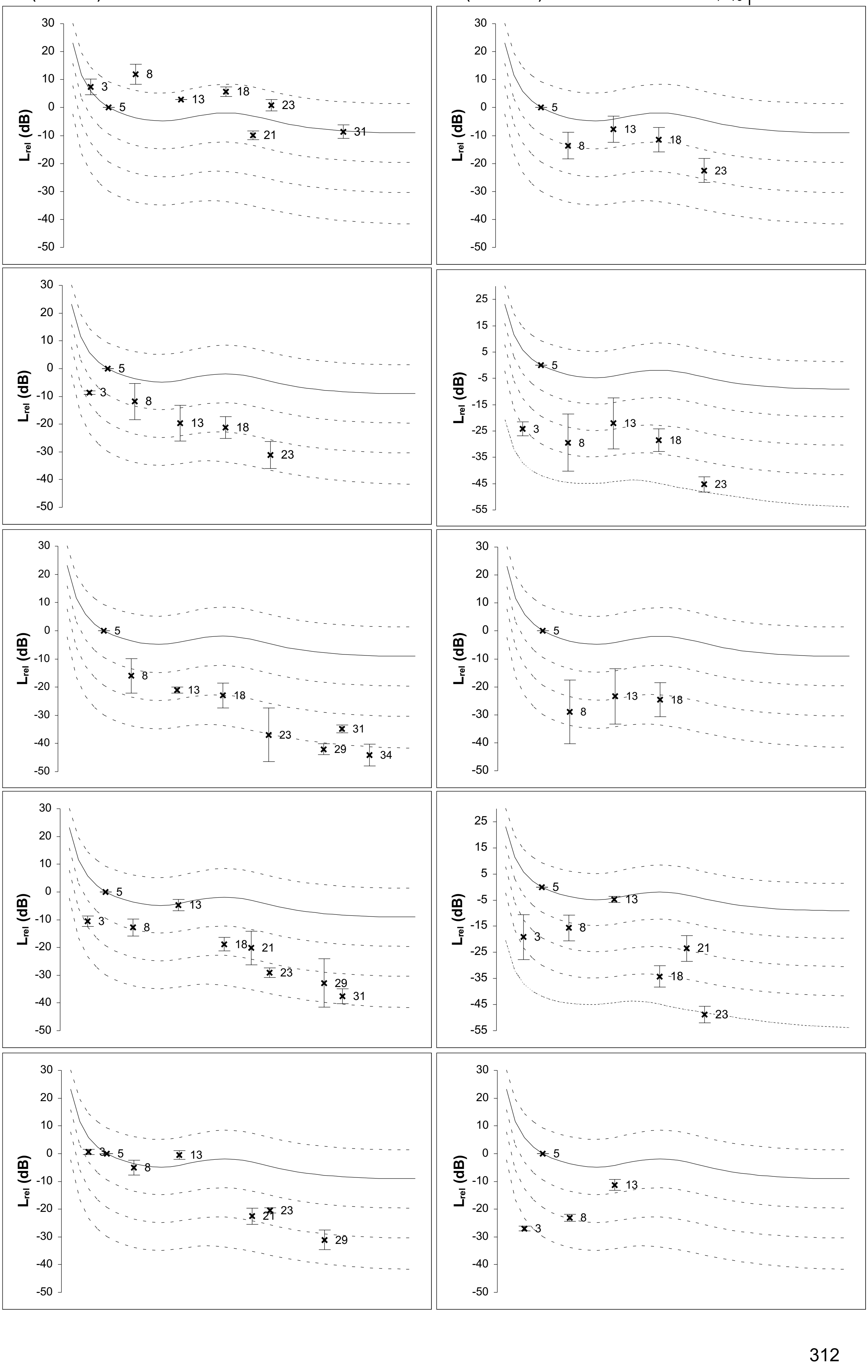
G1

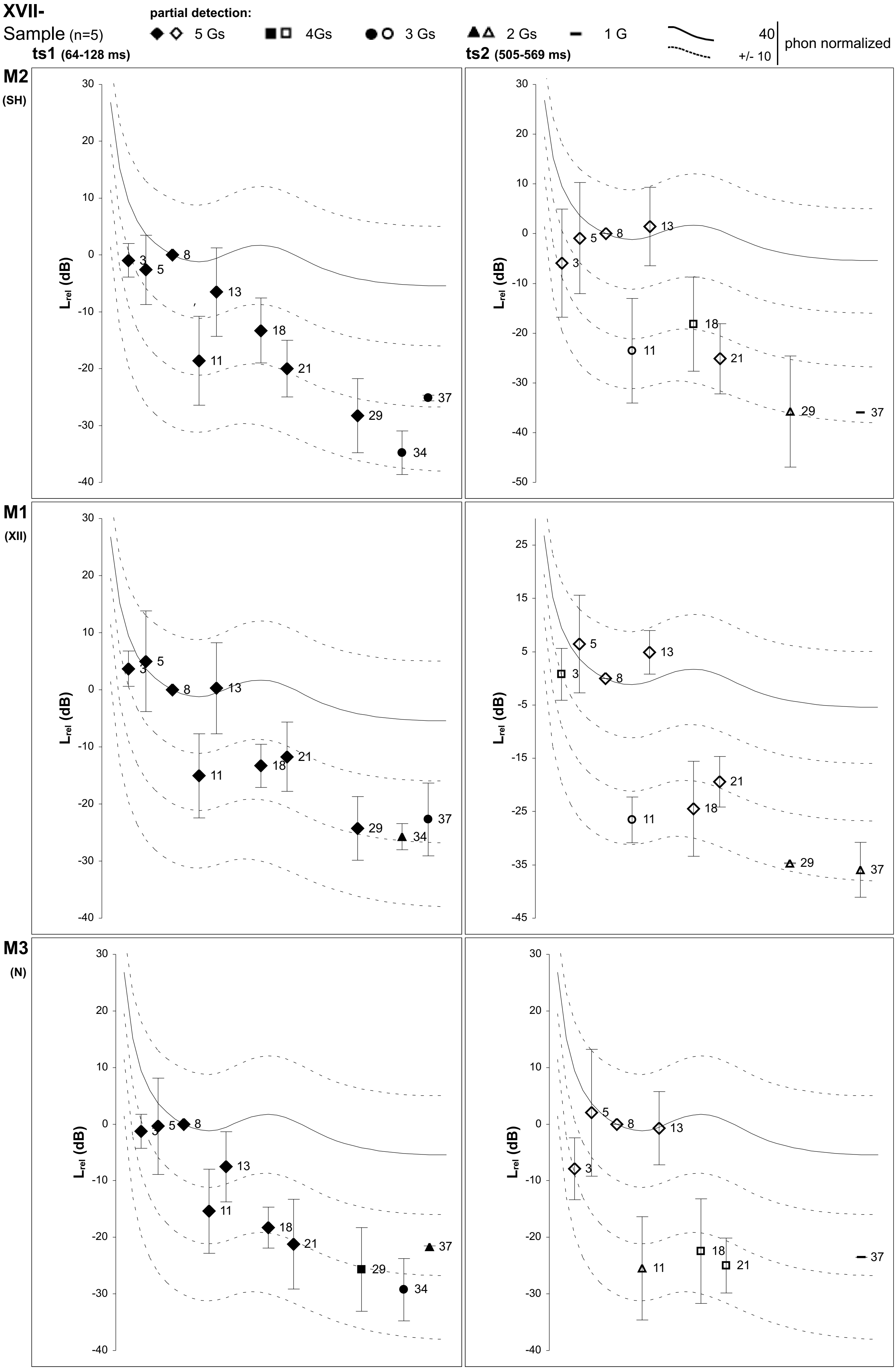
G2

G3

G4

G5

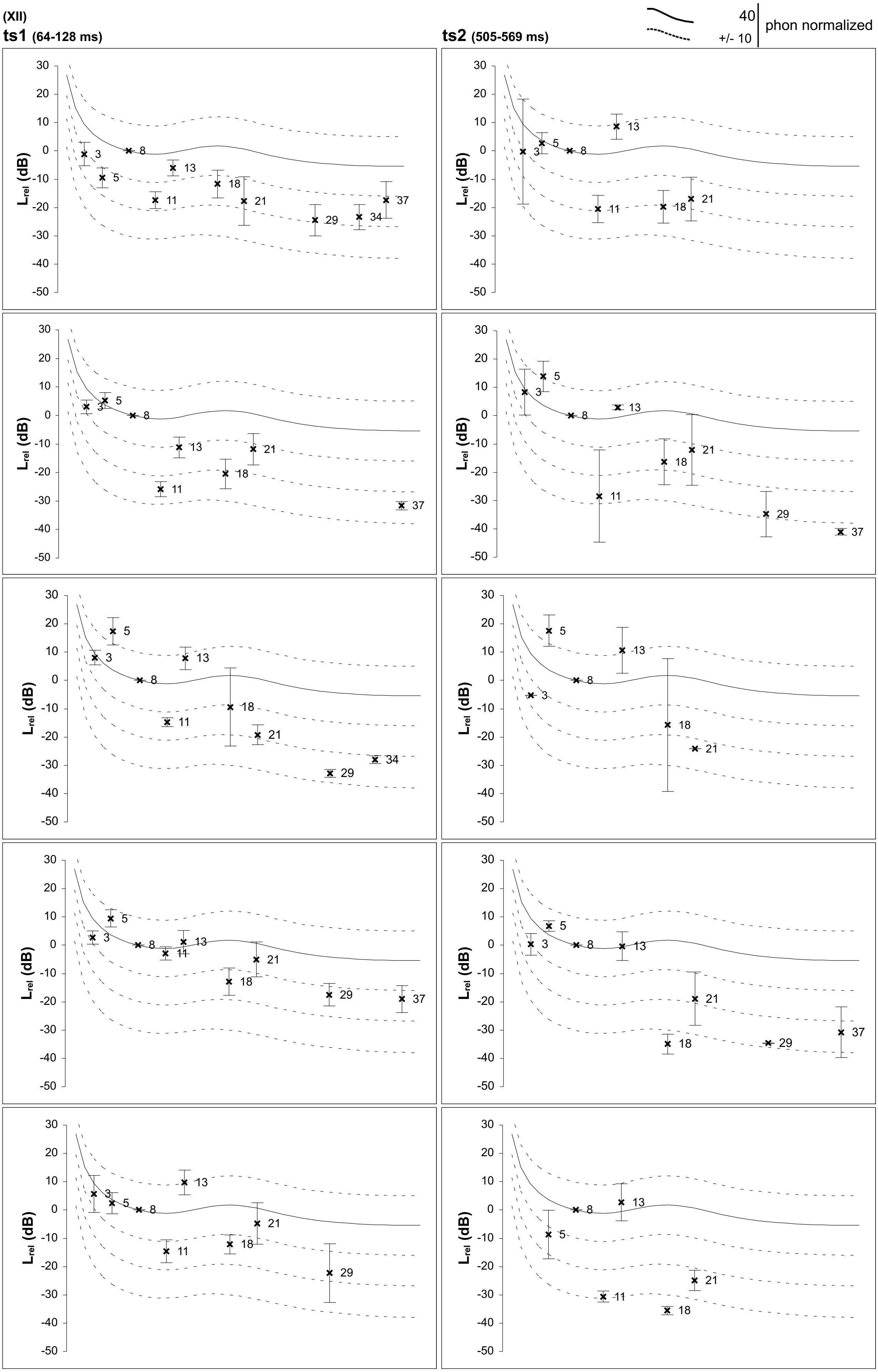



XVII-
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_rel (dB)
3
5
8
11
13
18
21
29
34
37

XVII-
M1 (XII)

ts1 (64-128 ms) **ts2** (505-569 ms)

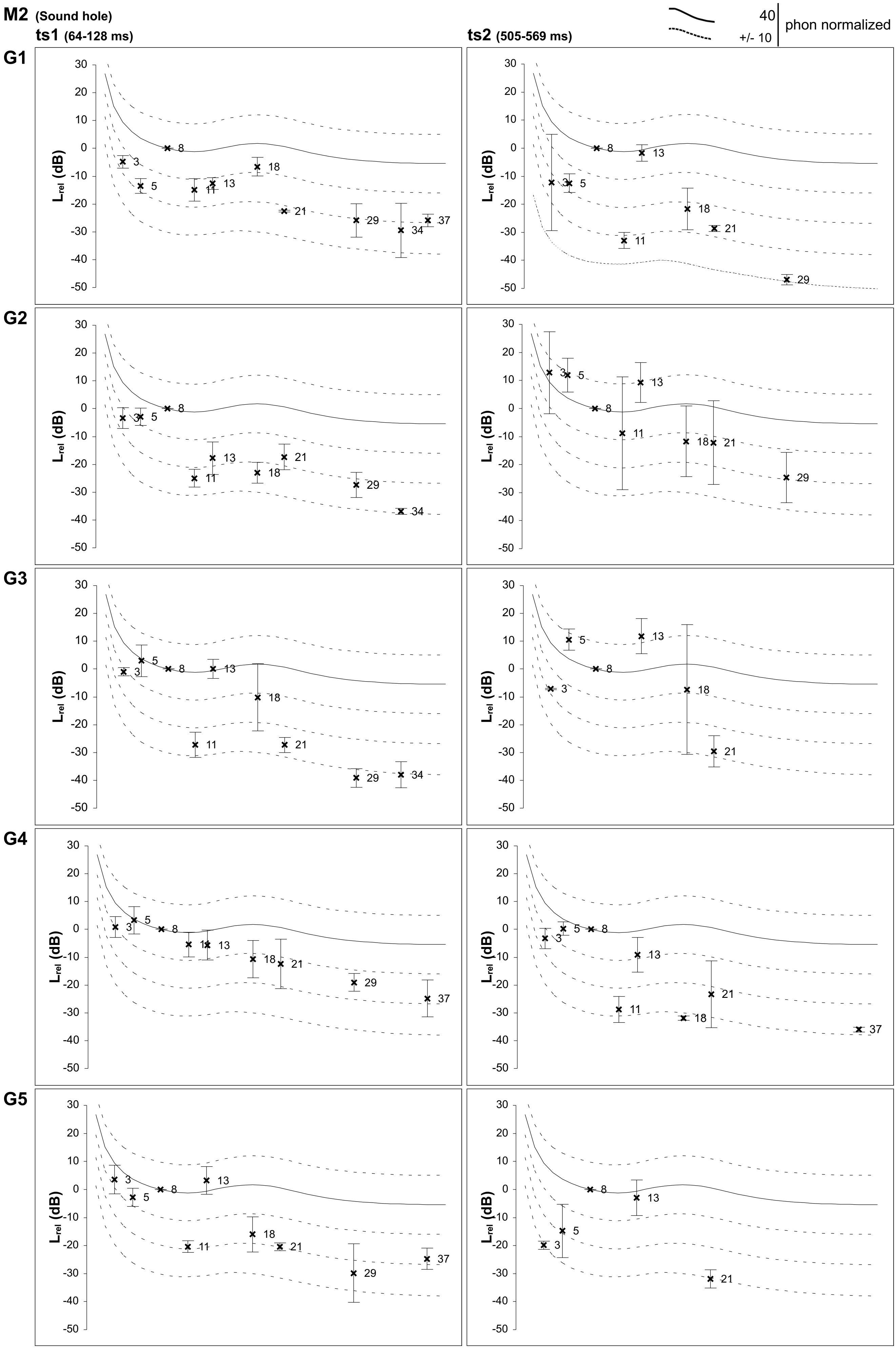
G1 G2 G3 G4 G5



XVII-

M2 (Sound hole)

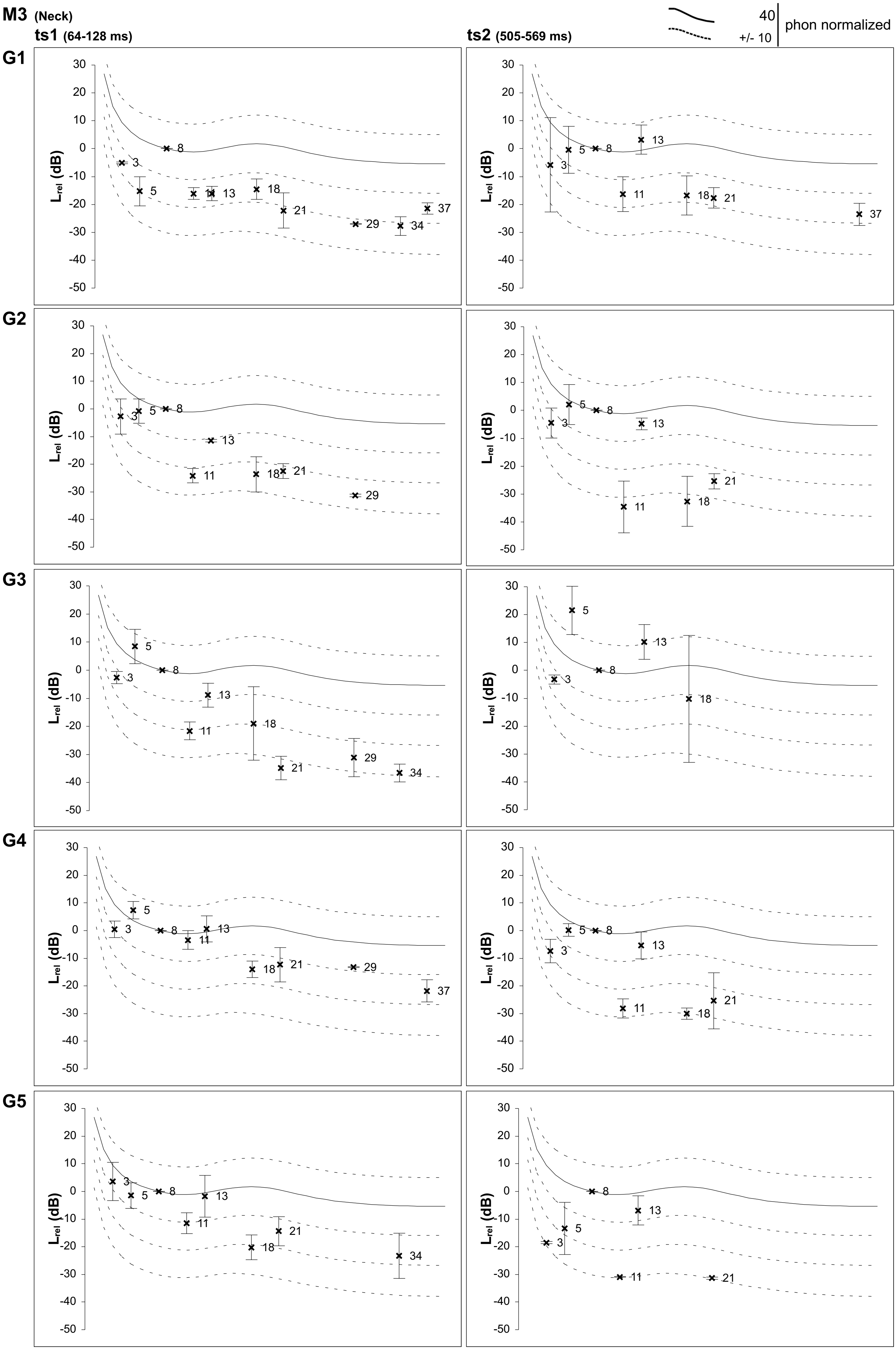
ts1 (64-128 ms) **ts2** (505-569 ms)

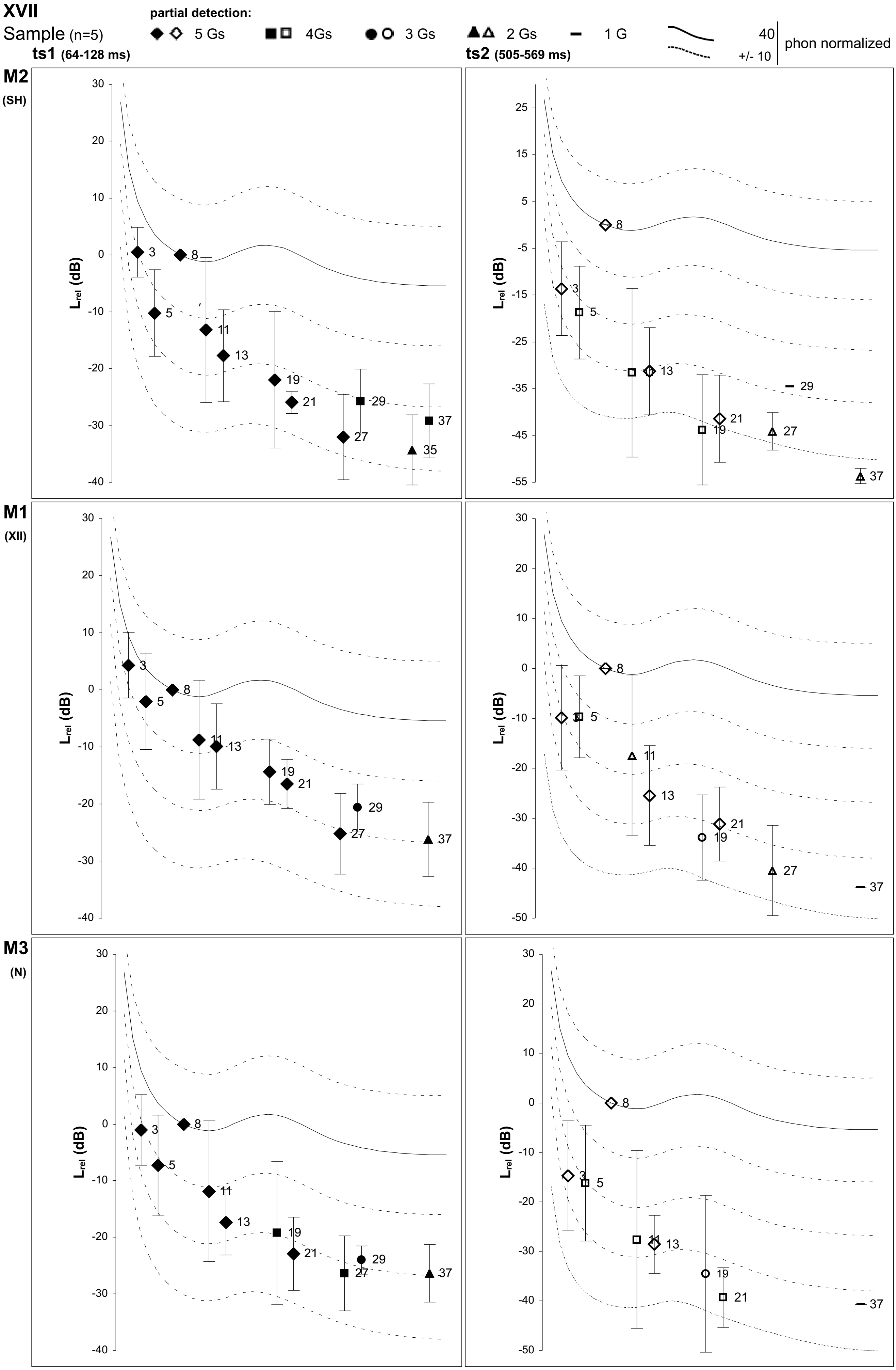


XVII-

M3 **(Neck)**

ts1 **(64-128 ms)** **ts2** **(505-569 ms)**




XVII
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_rel (dB)

XVII

M1 (XII)

ts1 (64-128 ms) **ts2** (505-569 ms)

40 phon normalized

+/- 10

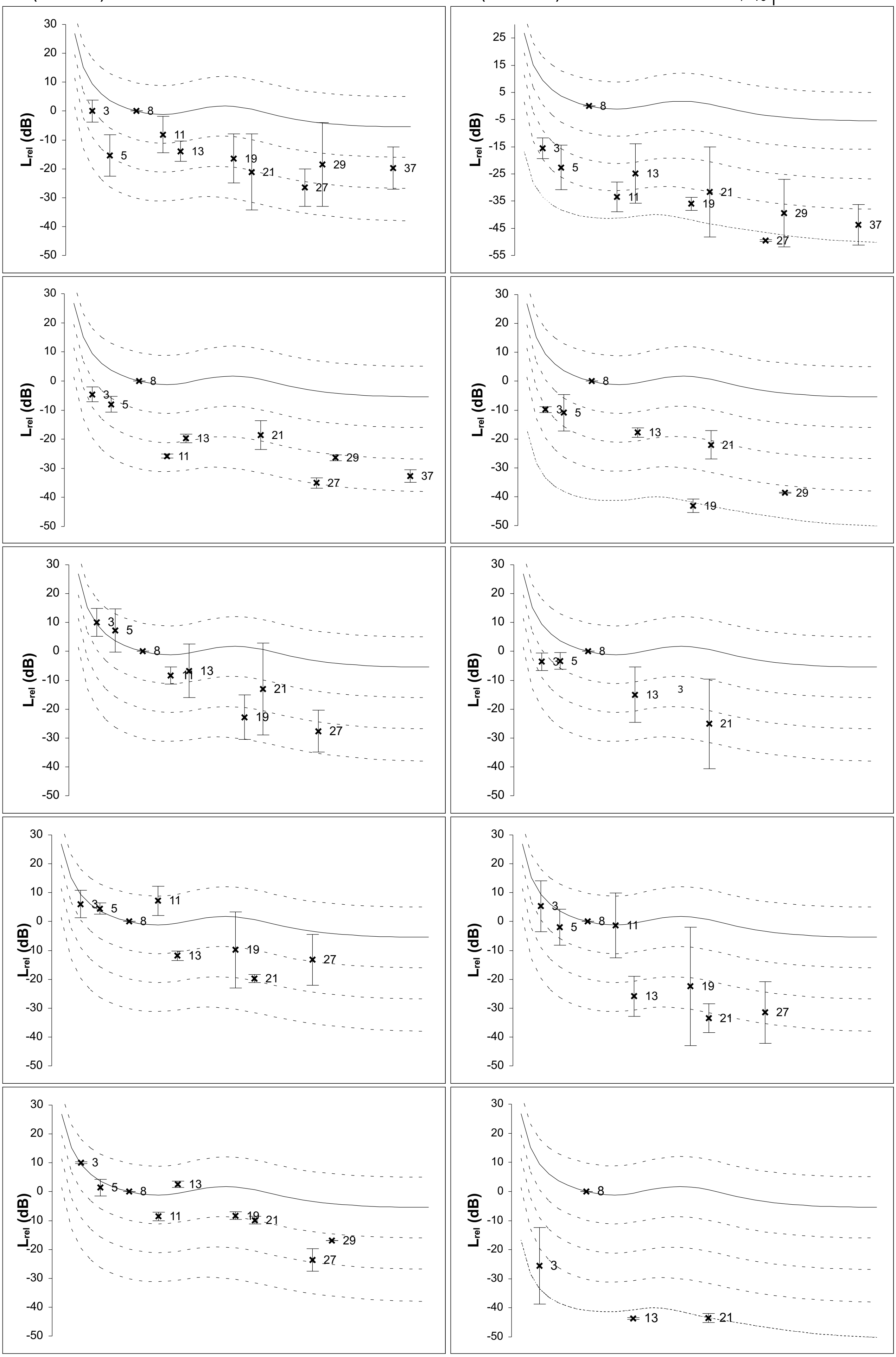
G1

G2

G3

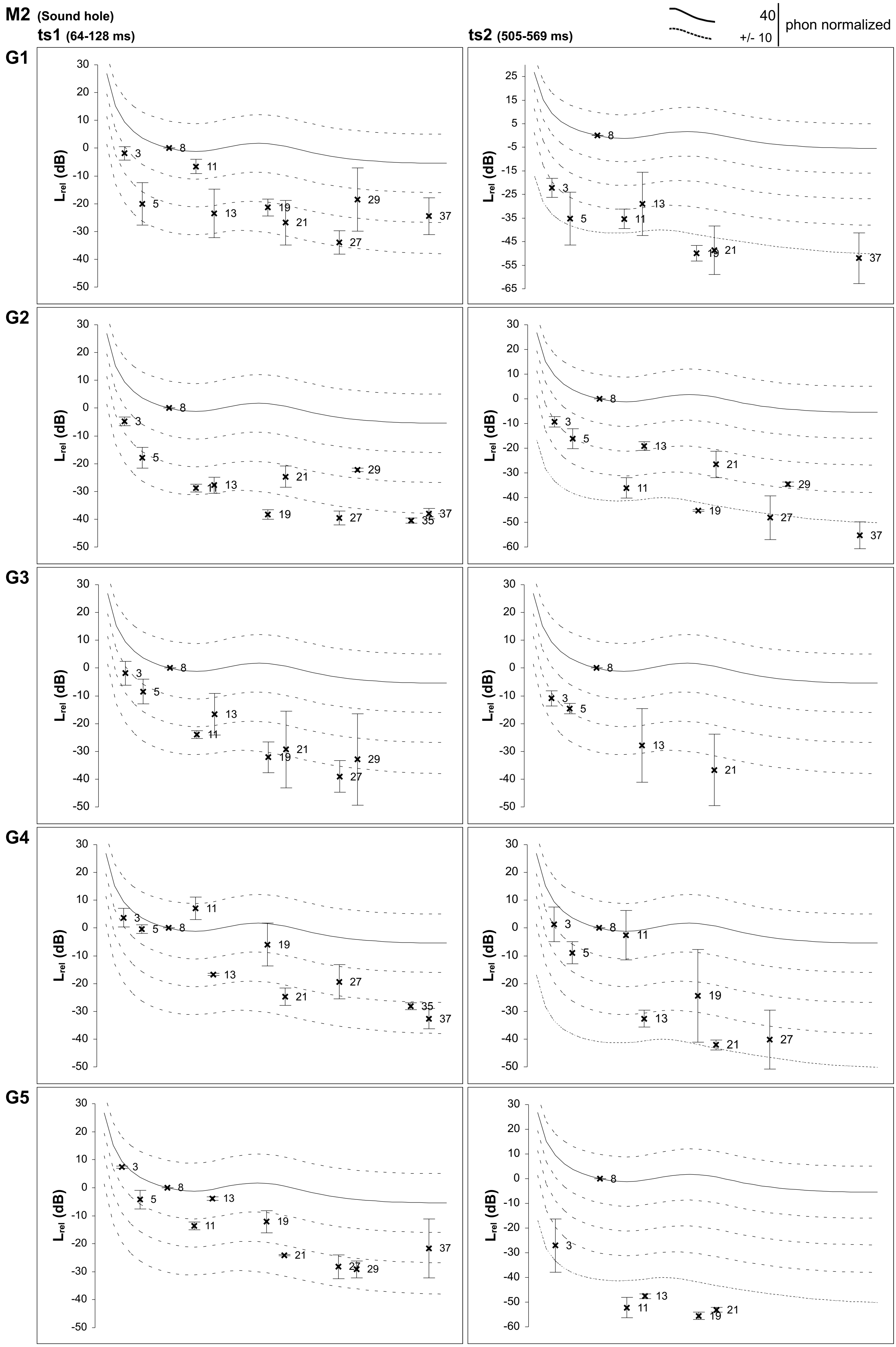
G4

G5



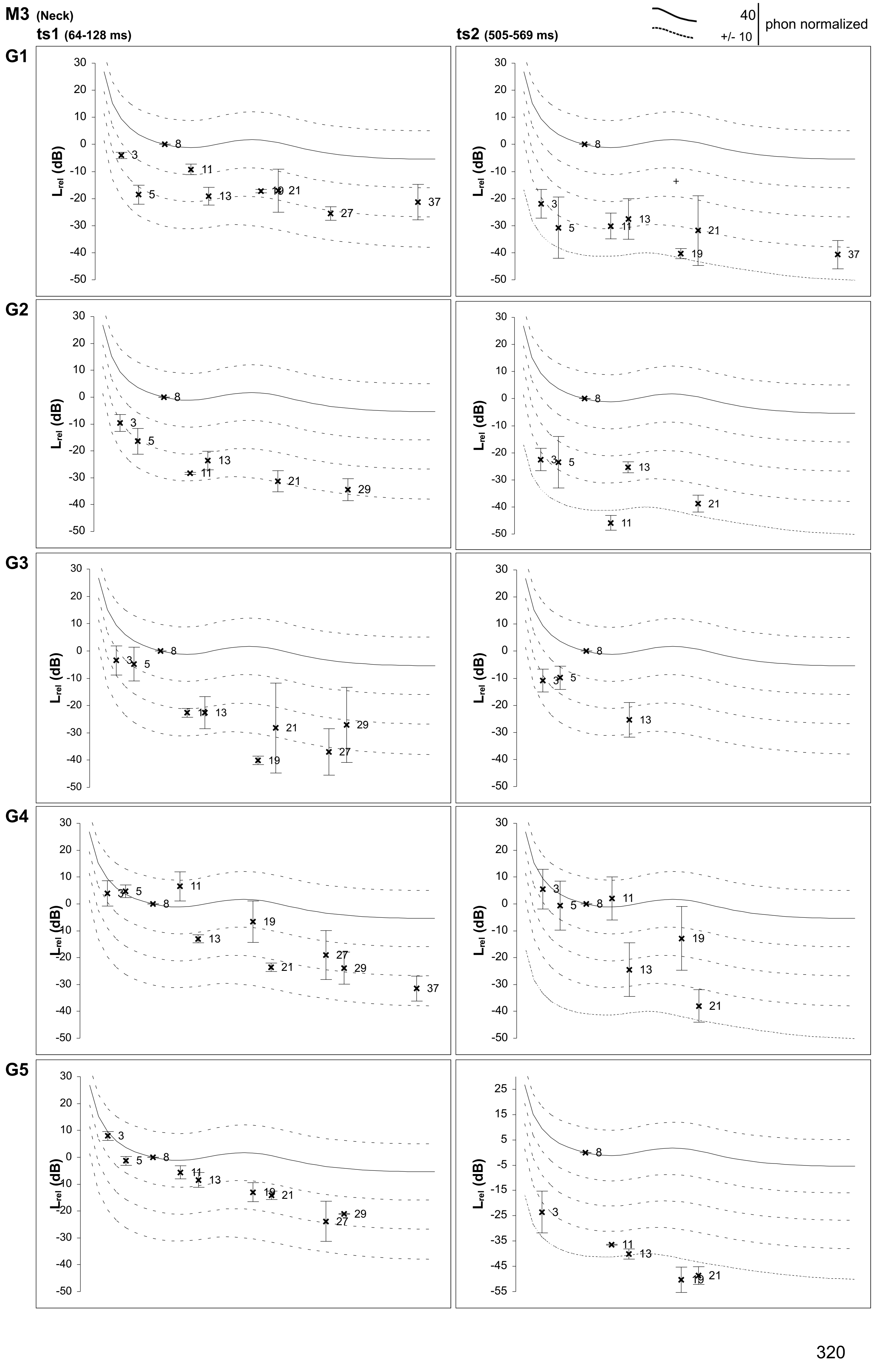
XVII

M2 (Sound hole)



XVII

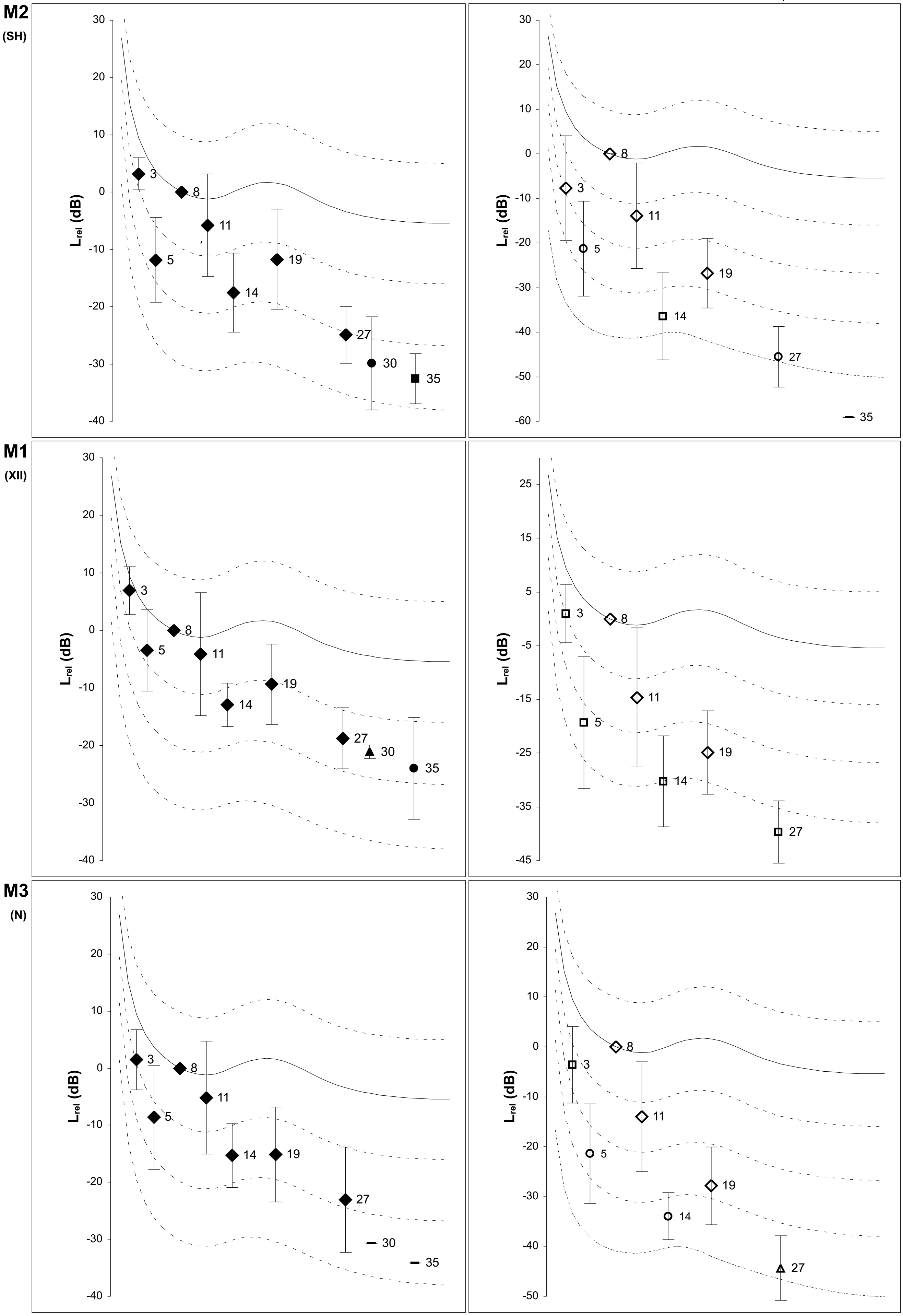
M3 (Neck)


ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
Lrel (dB)

XVII+ **partial detection:**

Sample (n=5) ◆◇ 5 Gs ■□ 4Gs ●○ 3 Gs ▲△ 2 Gs ▬ 1 G — 40 ┆ +/- 10 phon normalized

ts1 (64-128 ms) **ts2 (505-569 ms)**

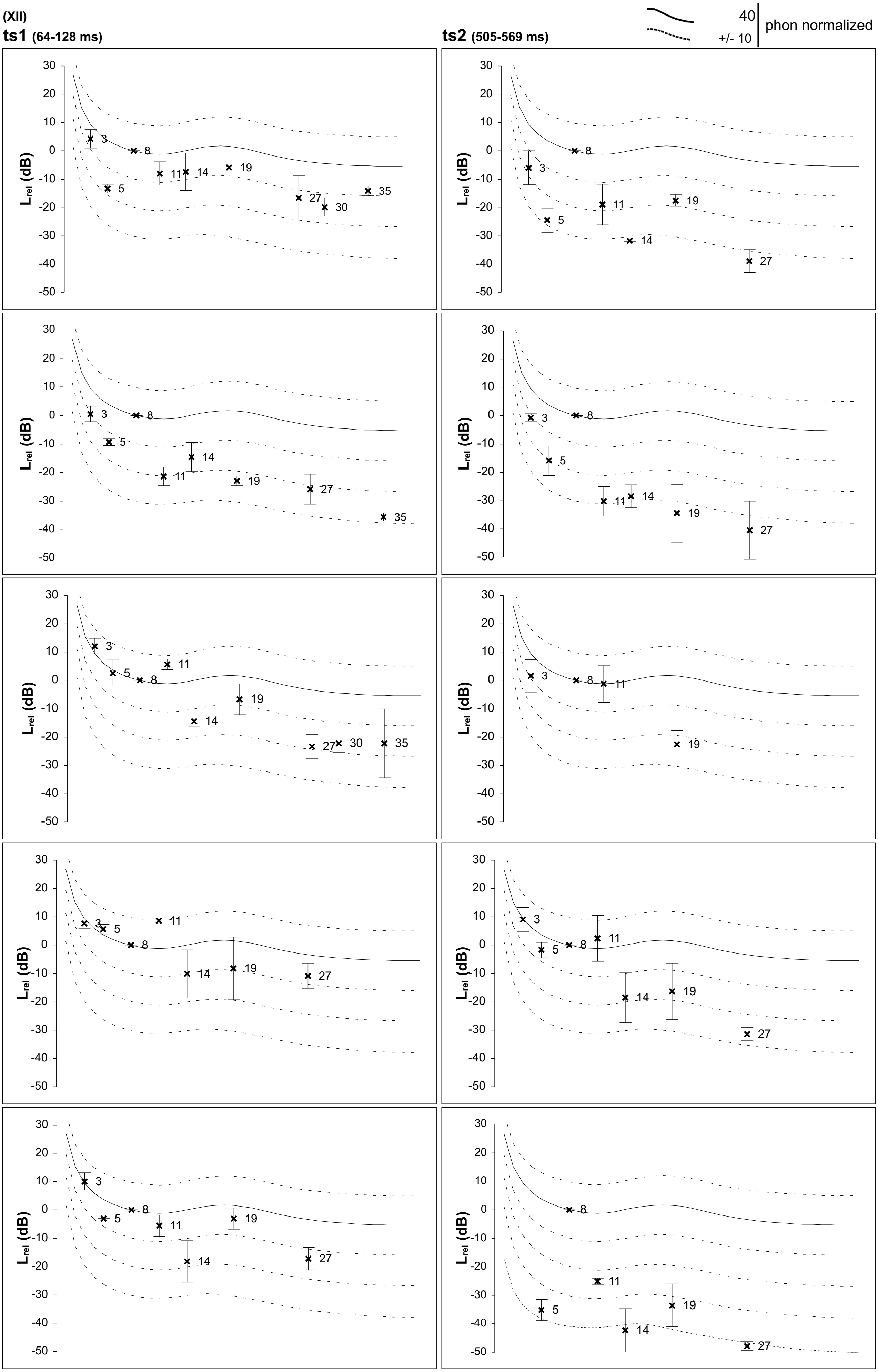


XVII+

M1 (XII)

ts1 (64-128 ms) **ts2** (505-569 ms)

G1 G2 G3 G4 G5



XVII+

M2 (Sound hole)

40 / +/- 10 — phon normalized

ts1 (64-128 ms) | **ts2** (505-569 ms)

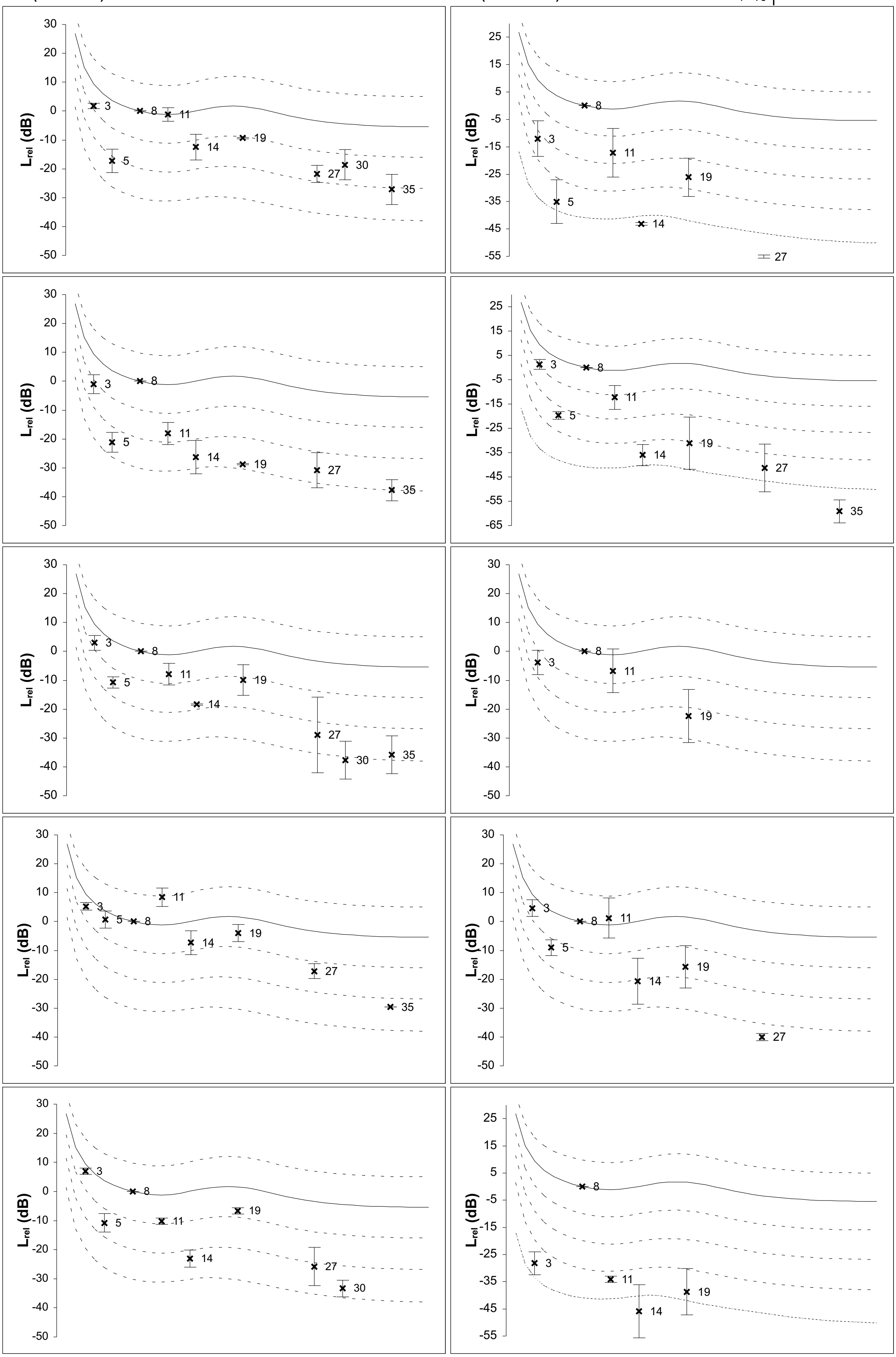
G1

G2

G3

G4

G5

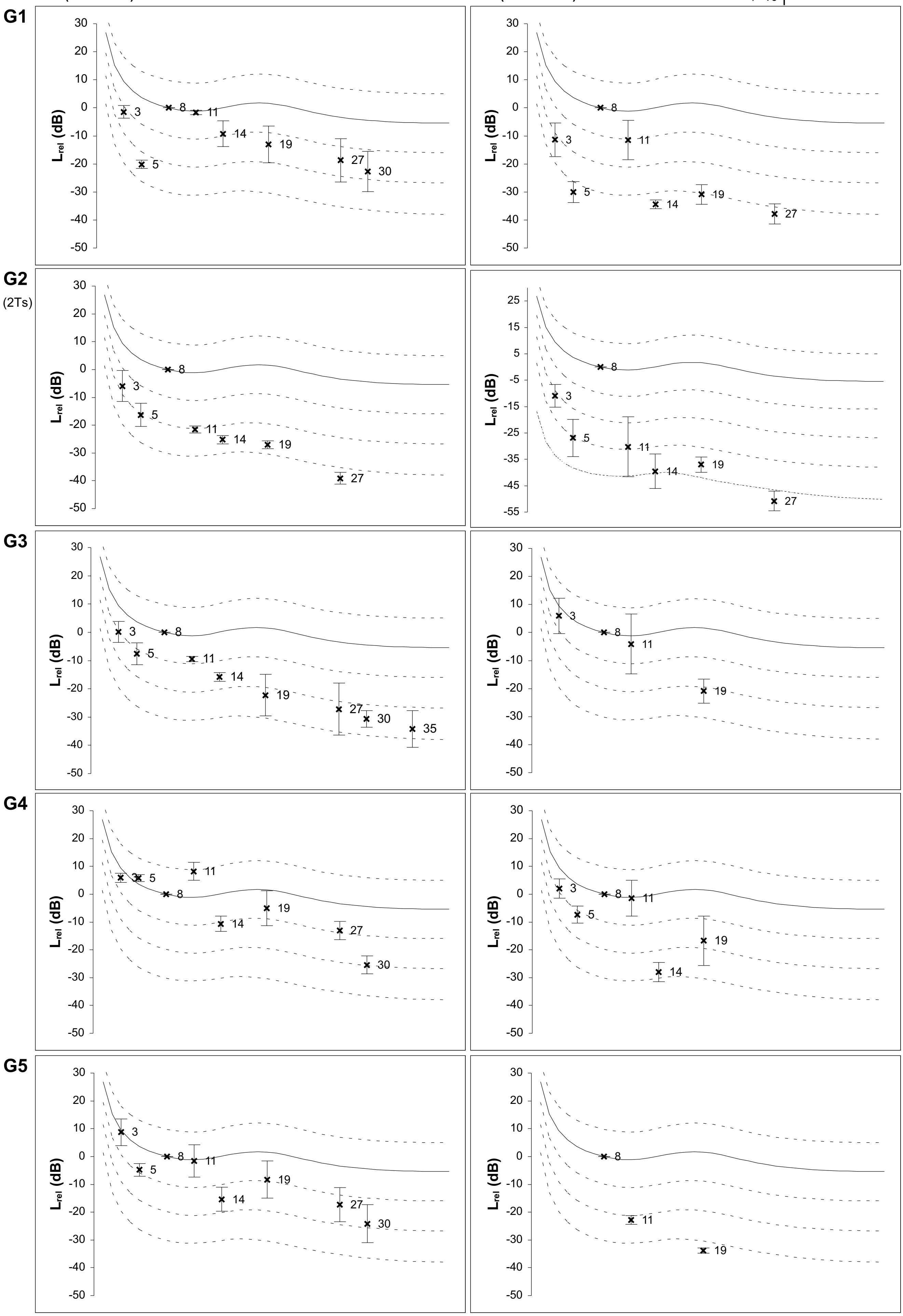


XVII+

M3 (Neck)

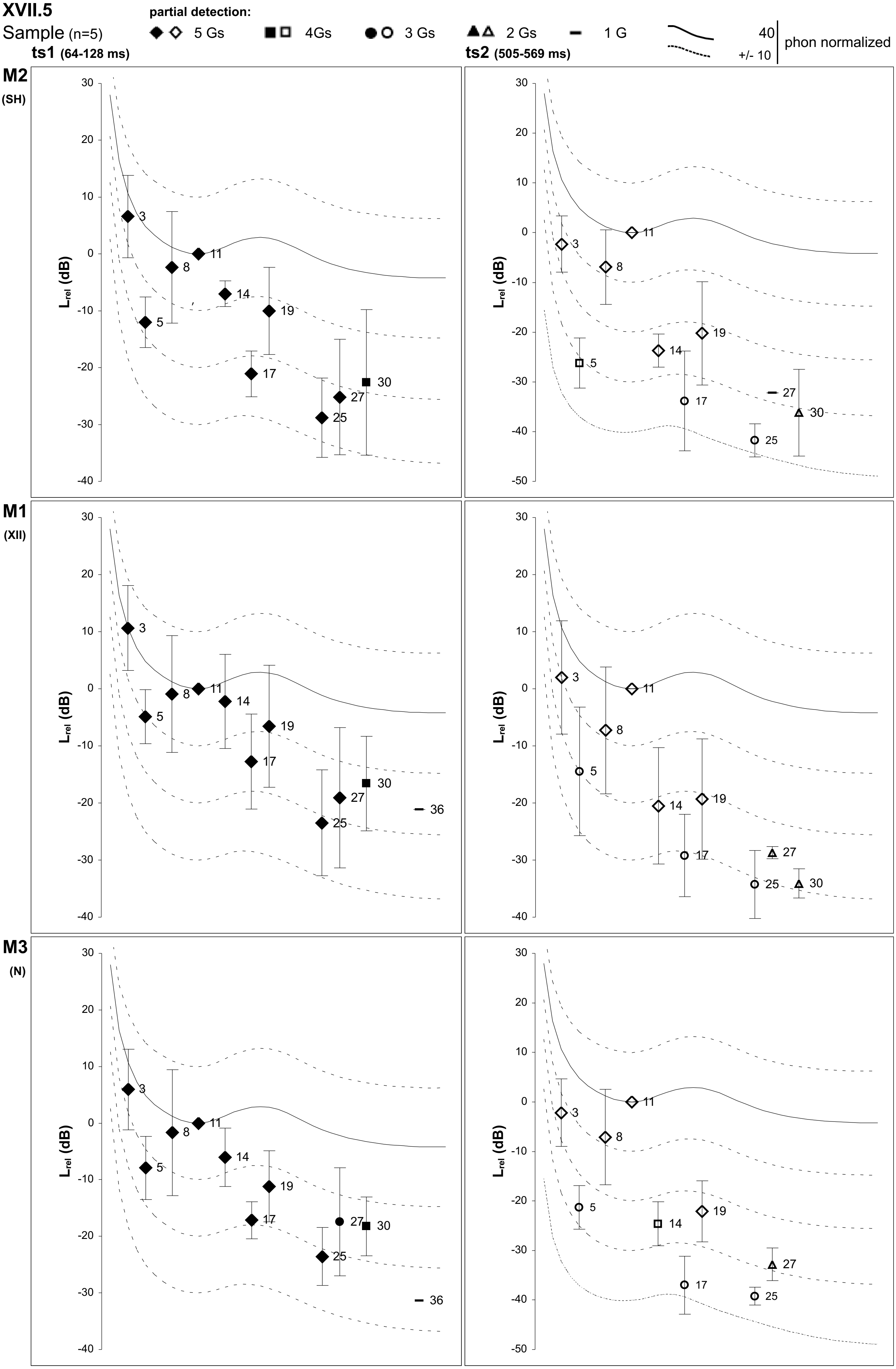
ts1 (64-128 ms) **ts2** (505-569 ms)

40 / +/- 10 phon normalized



XVII.5

Sample (n=5)



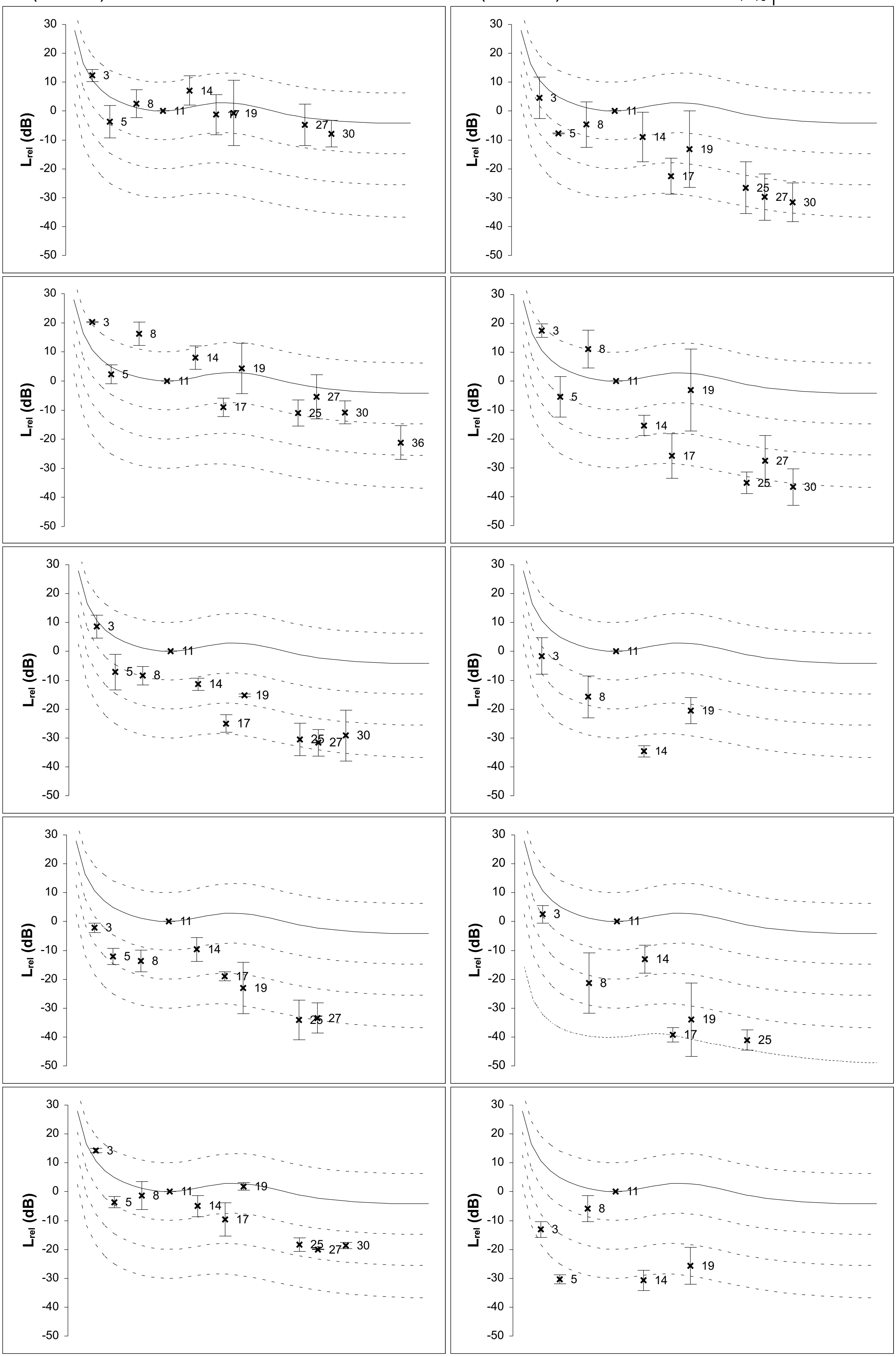
XVII.5

M1 (XII)

40 phon normalized
+/- 10

ts1 (64-128 ms) **ts2** (505-569 ms)

G1
G2
G3
G4
G5



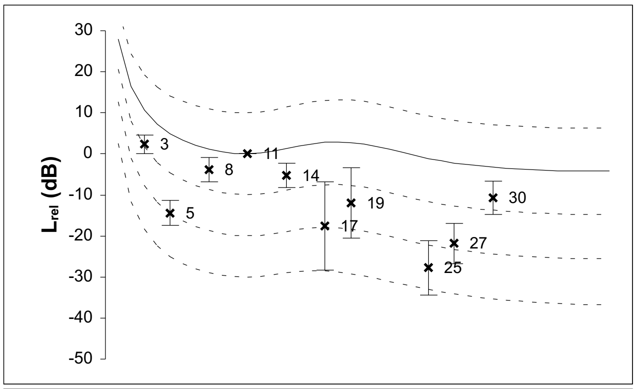
XVII.5

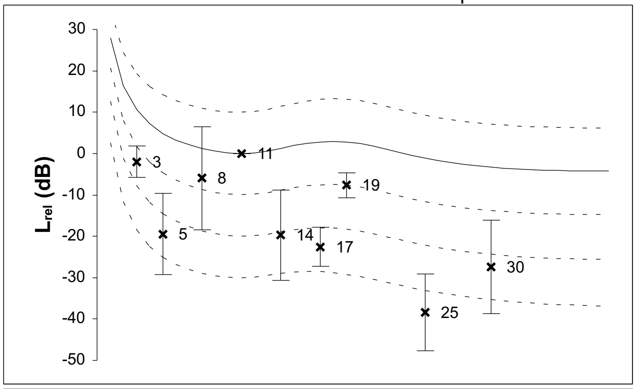
M2 **(Sound hole)**

40 | +/- 10 | phon normalized

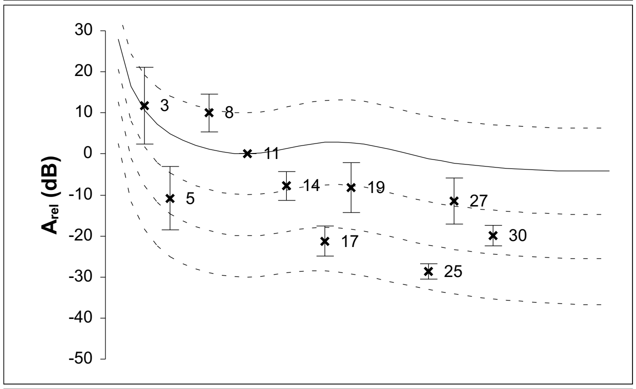
ts1 (64-128 ms) **ts2 (505-569 ms)**

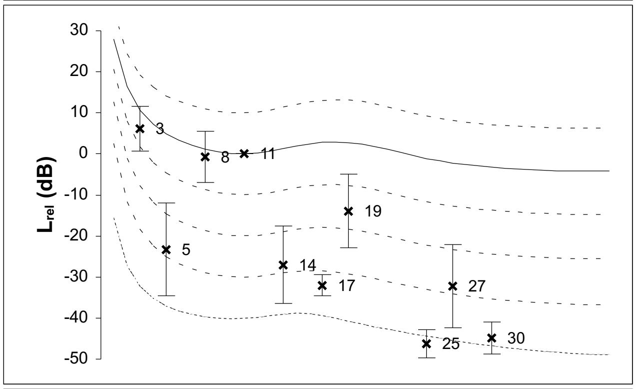
G1



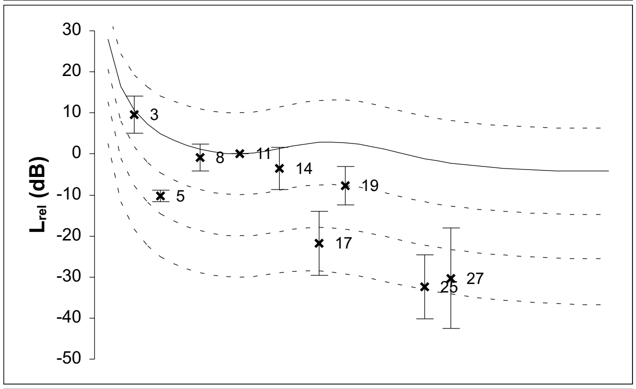


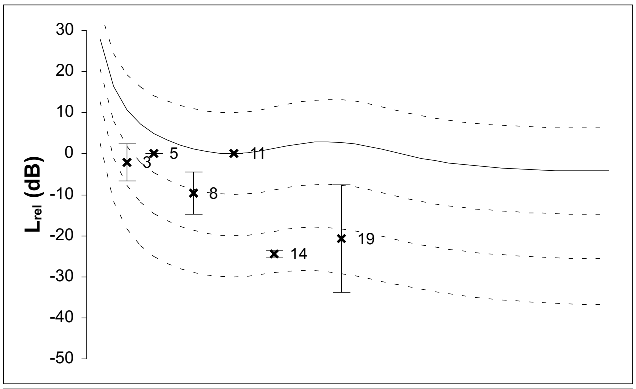
G2



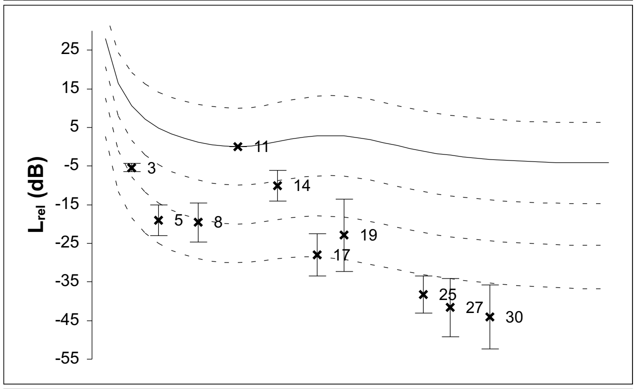


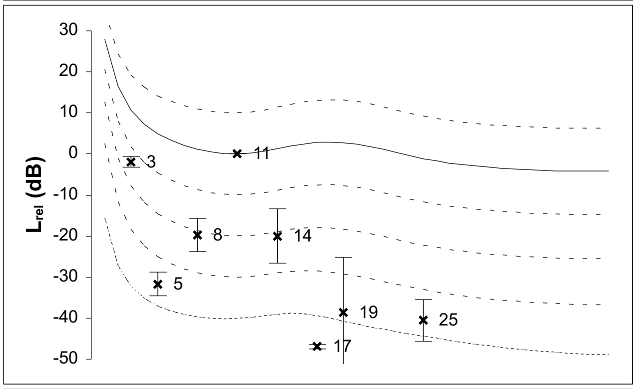
G3



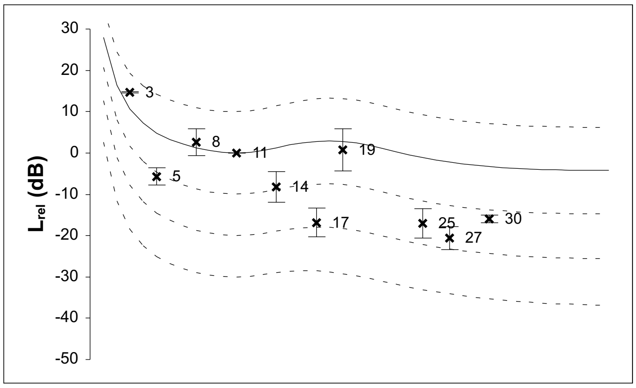


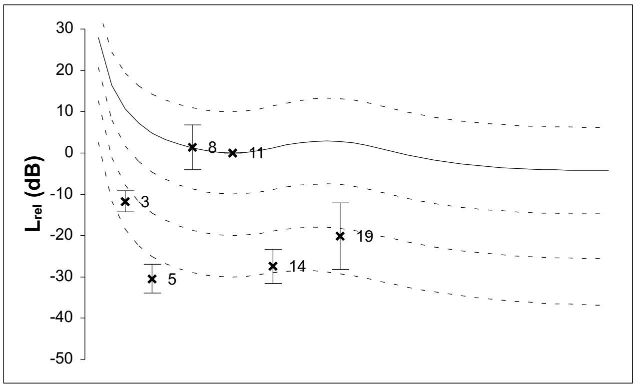
G4





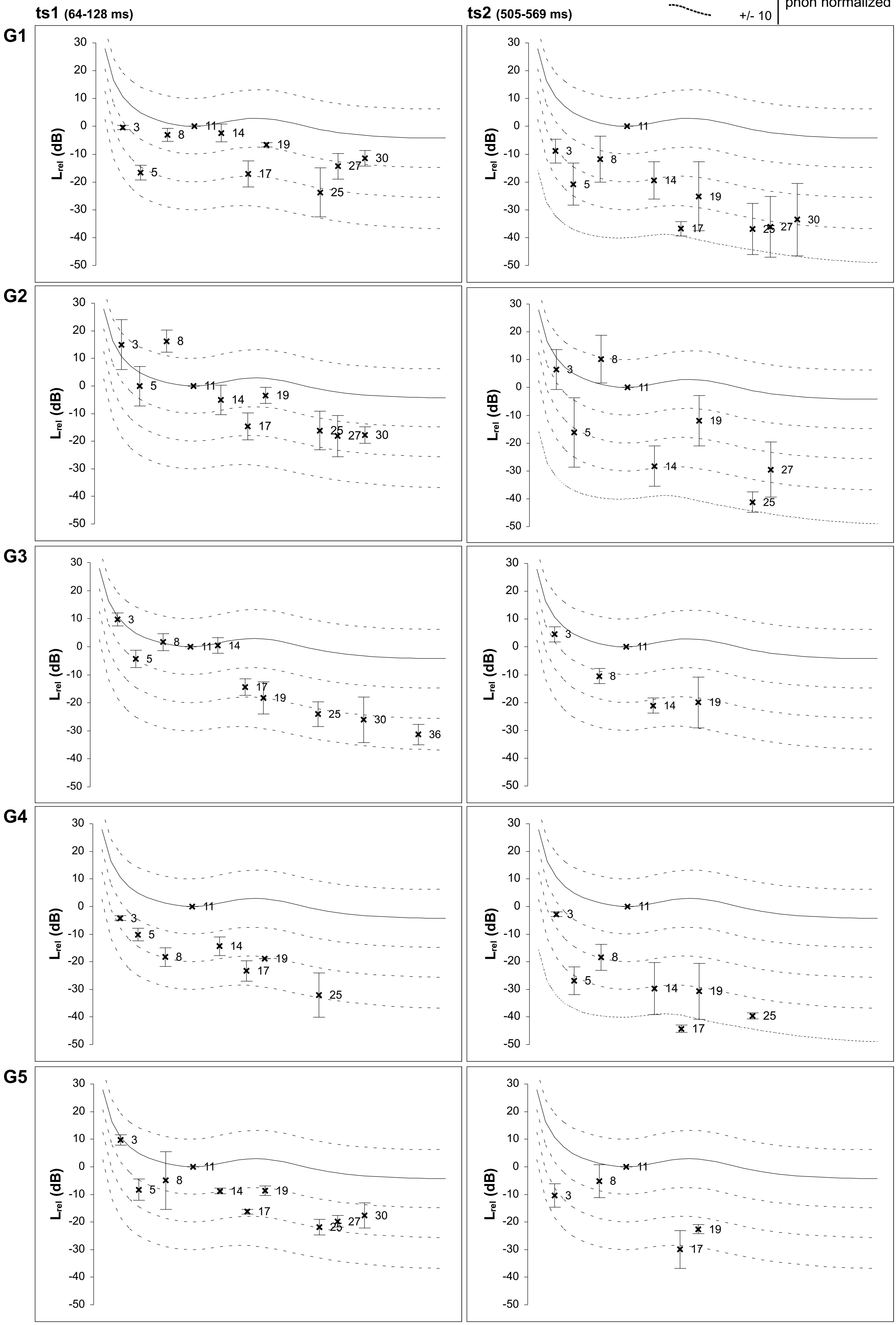
G5

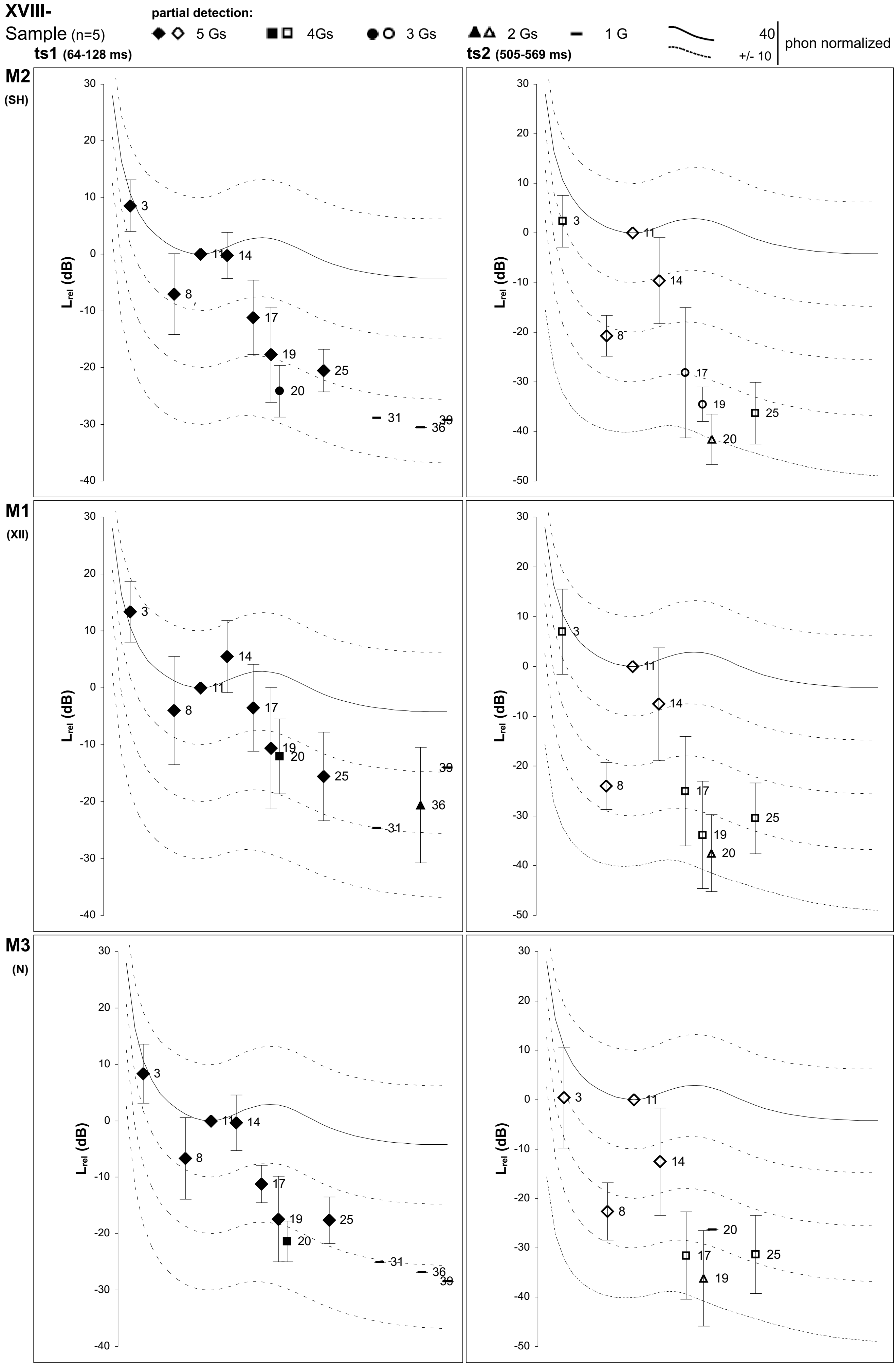




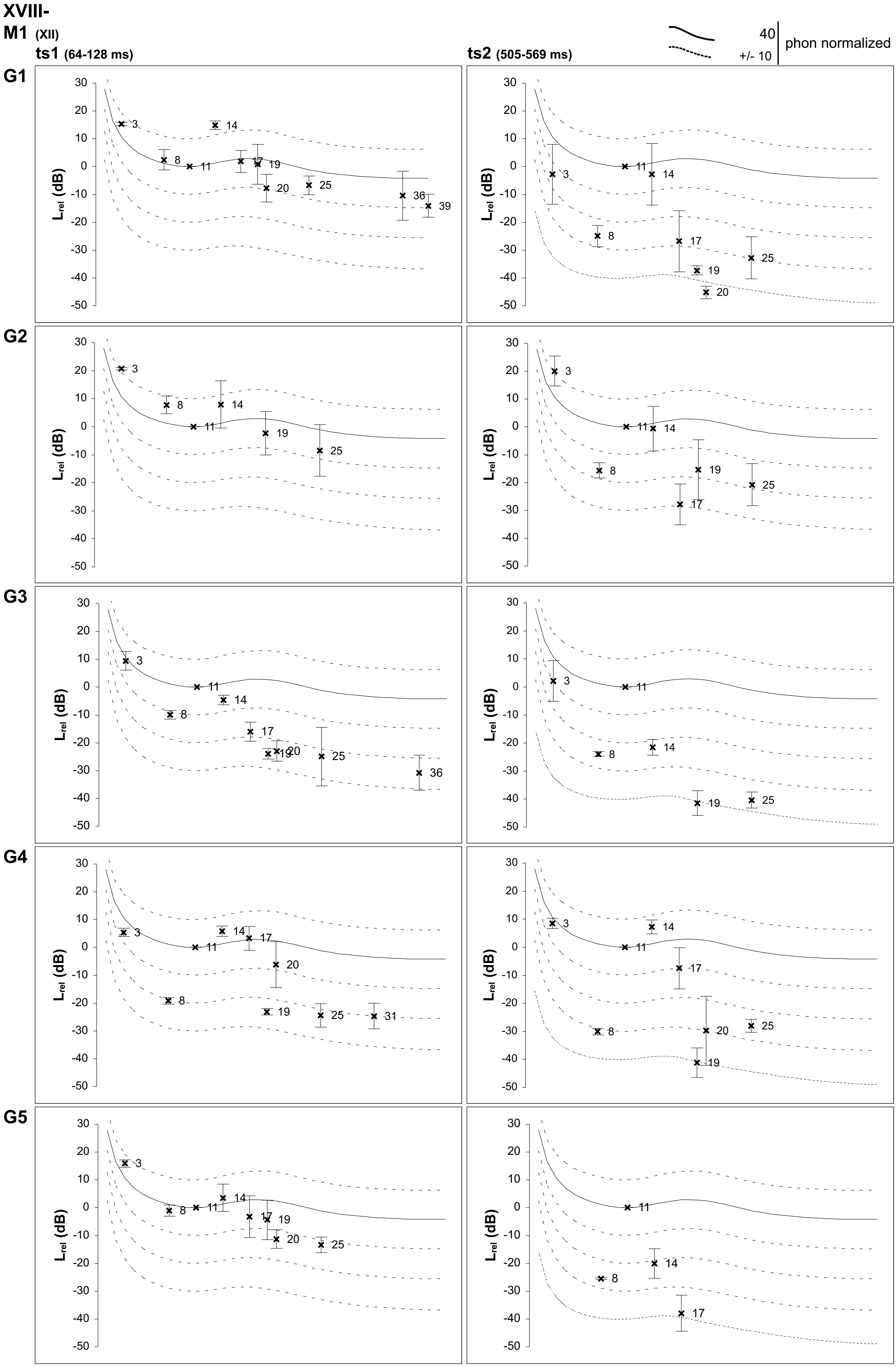
XVII.5

M3 **(Neck)**



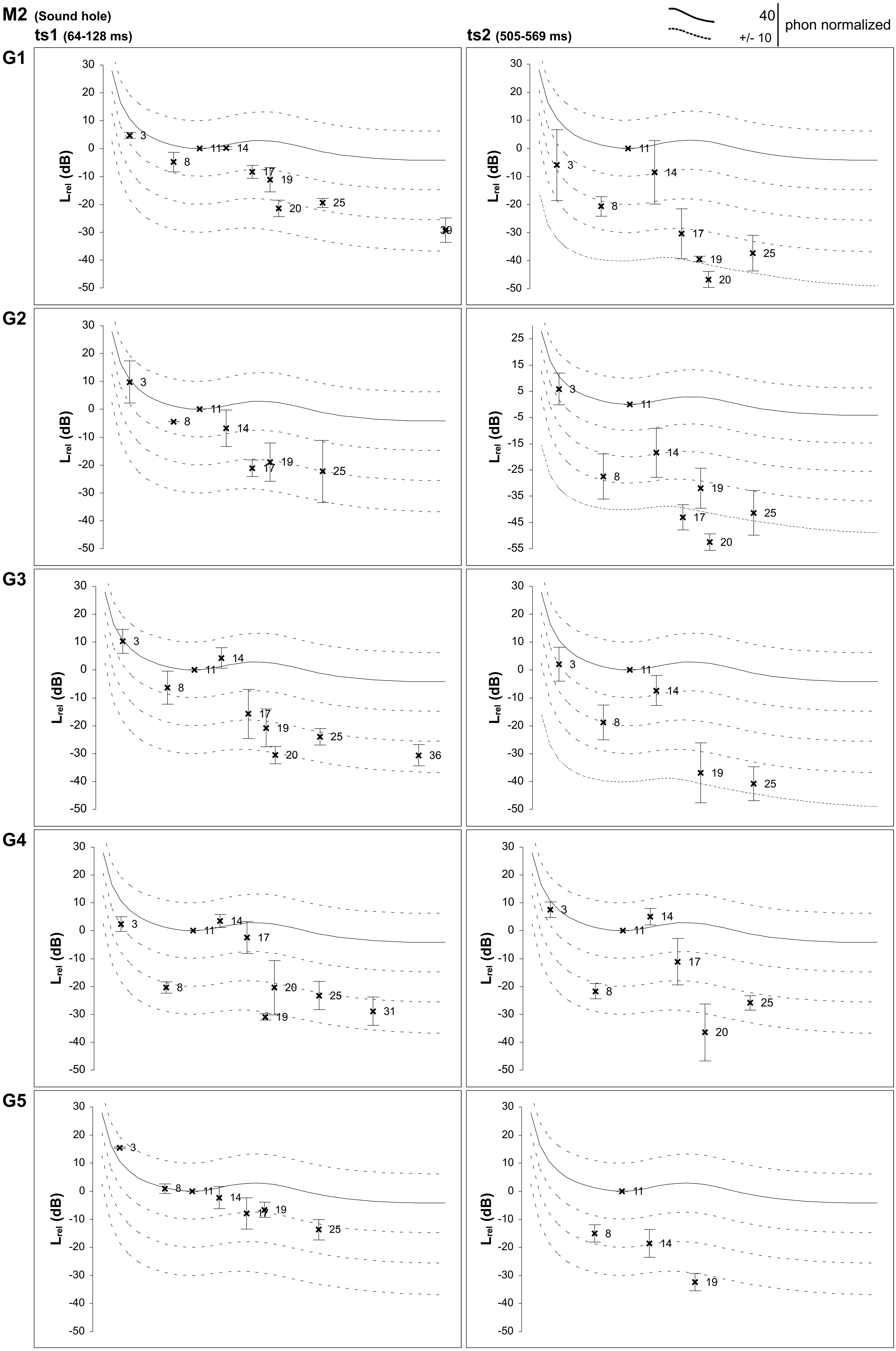


XVIII-
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_rel (dB)


XVIII-
M1 (XII)
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
Lrel (dB)

XVIII-

M2 (Sound hole)

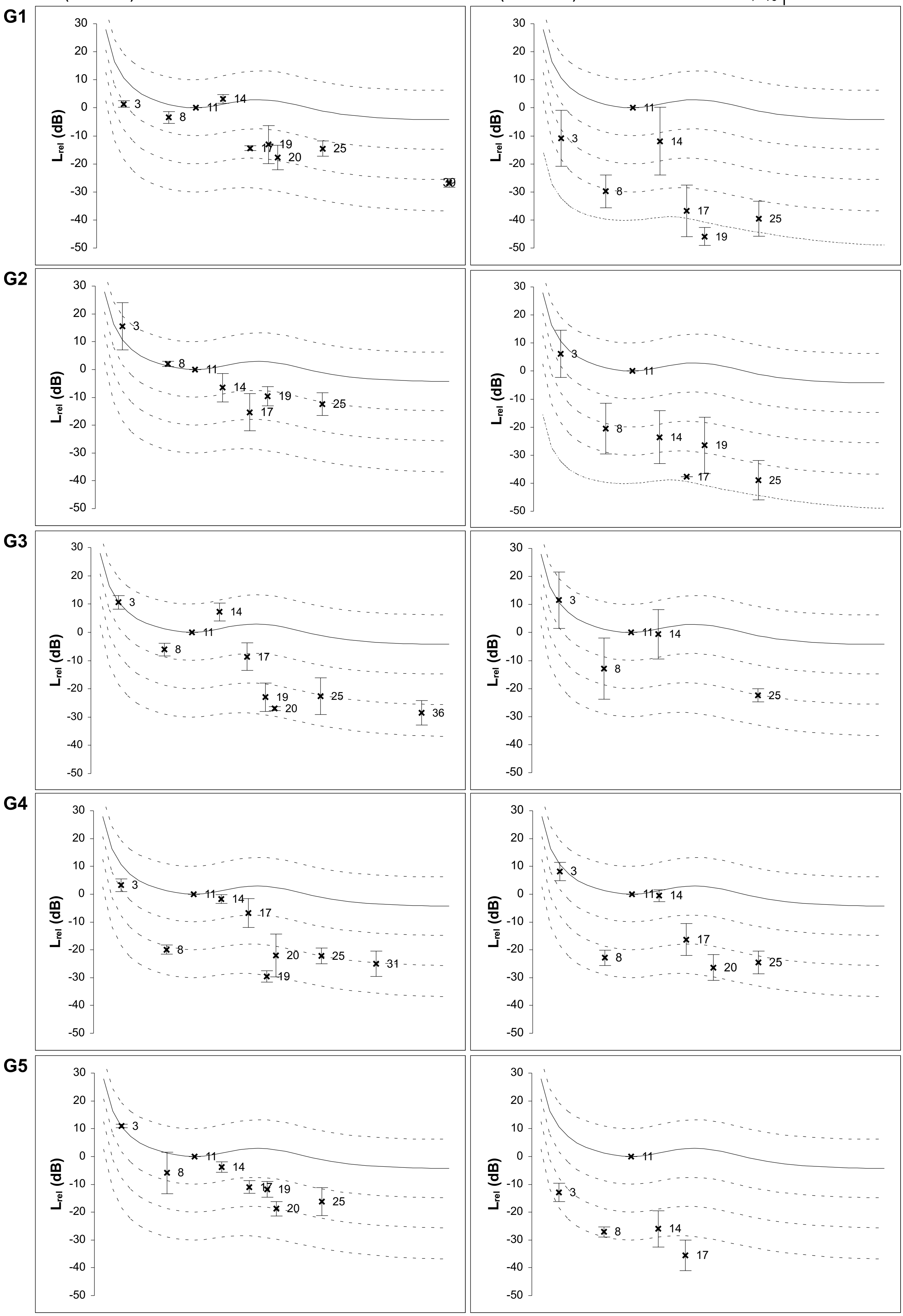


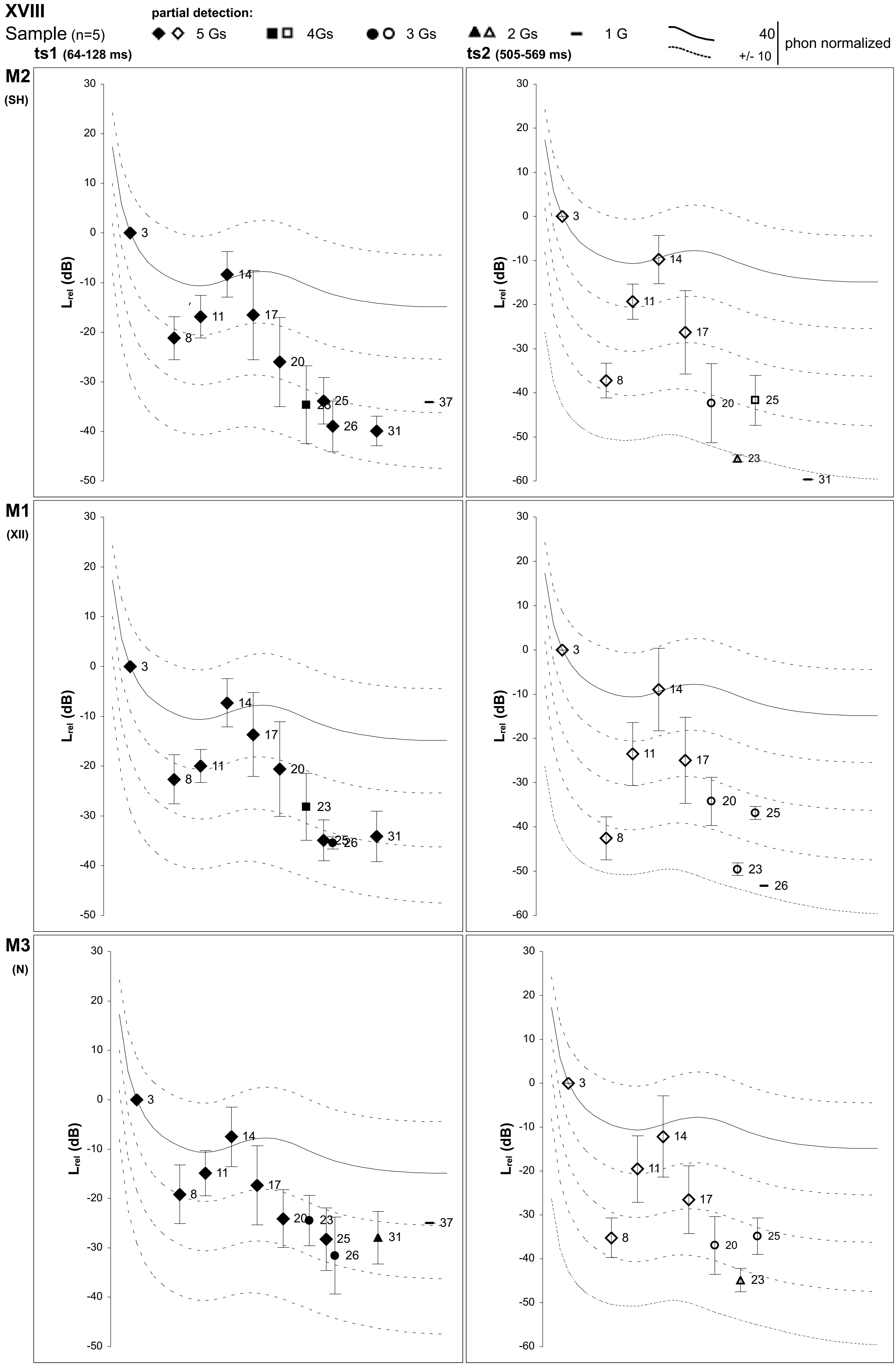
XVIII-

M3 (Neck)

40 | phon normalized
+/- 10

ts1 (64-128 ms) **ts2** (505-569 ms)




XVIII
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_rel (dB)

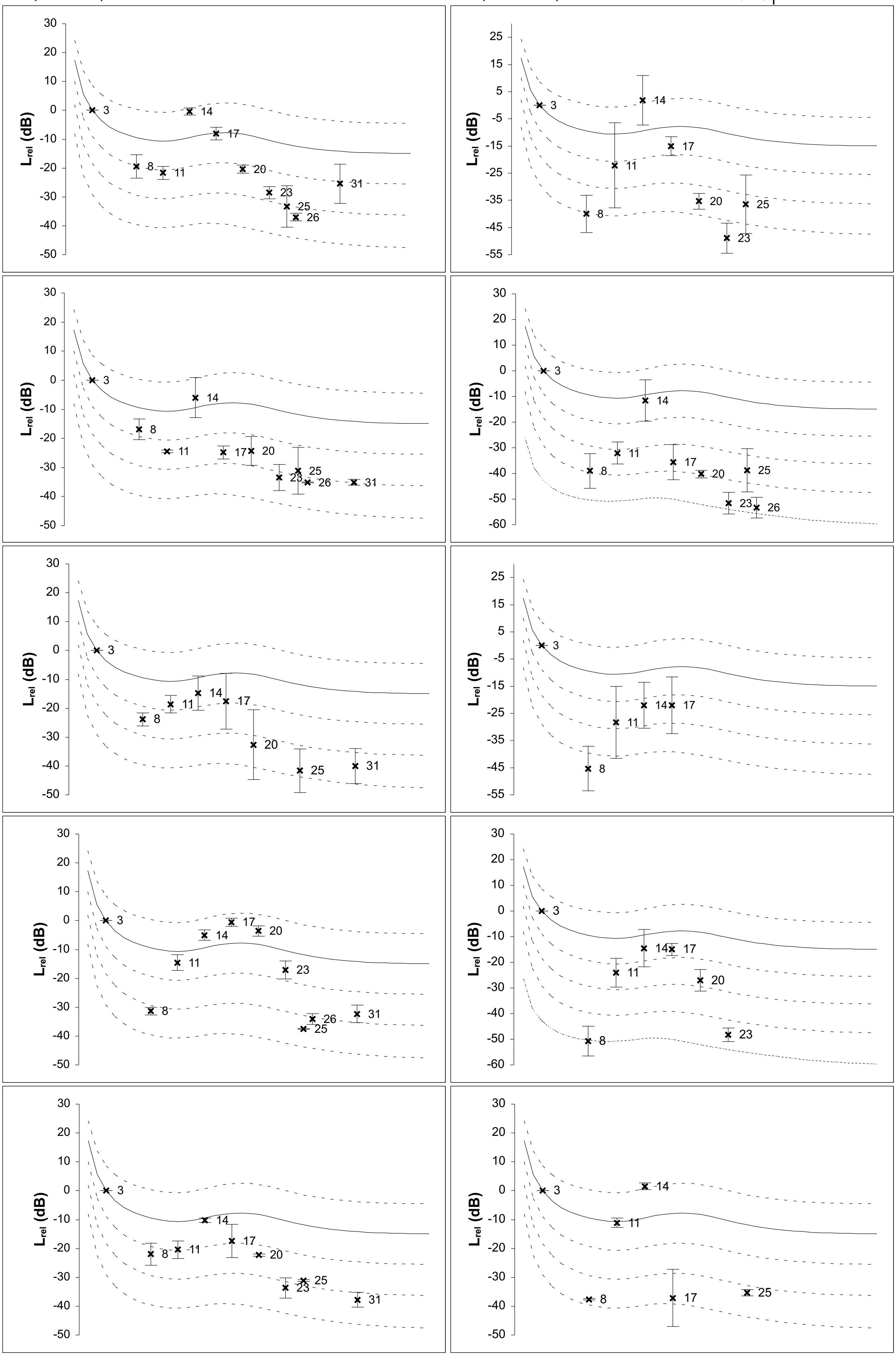
XVIII

M1 **(XII)**

ts1 **(64-128 ms)** **ts2** **(505-569 ms)**

40 | phon normalized
+/- 10

G1
G2
G3
G4
G5



XVIII

M2 (Sound hole)

ts1 (64-128 ms) | **ts2 (505-569 ms)**

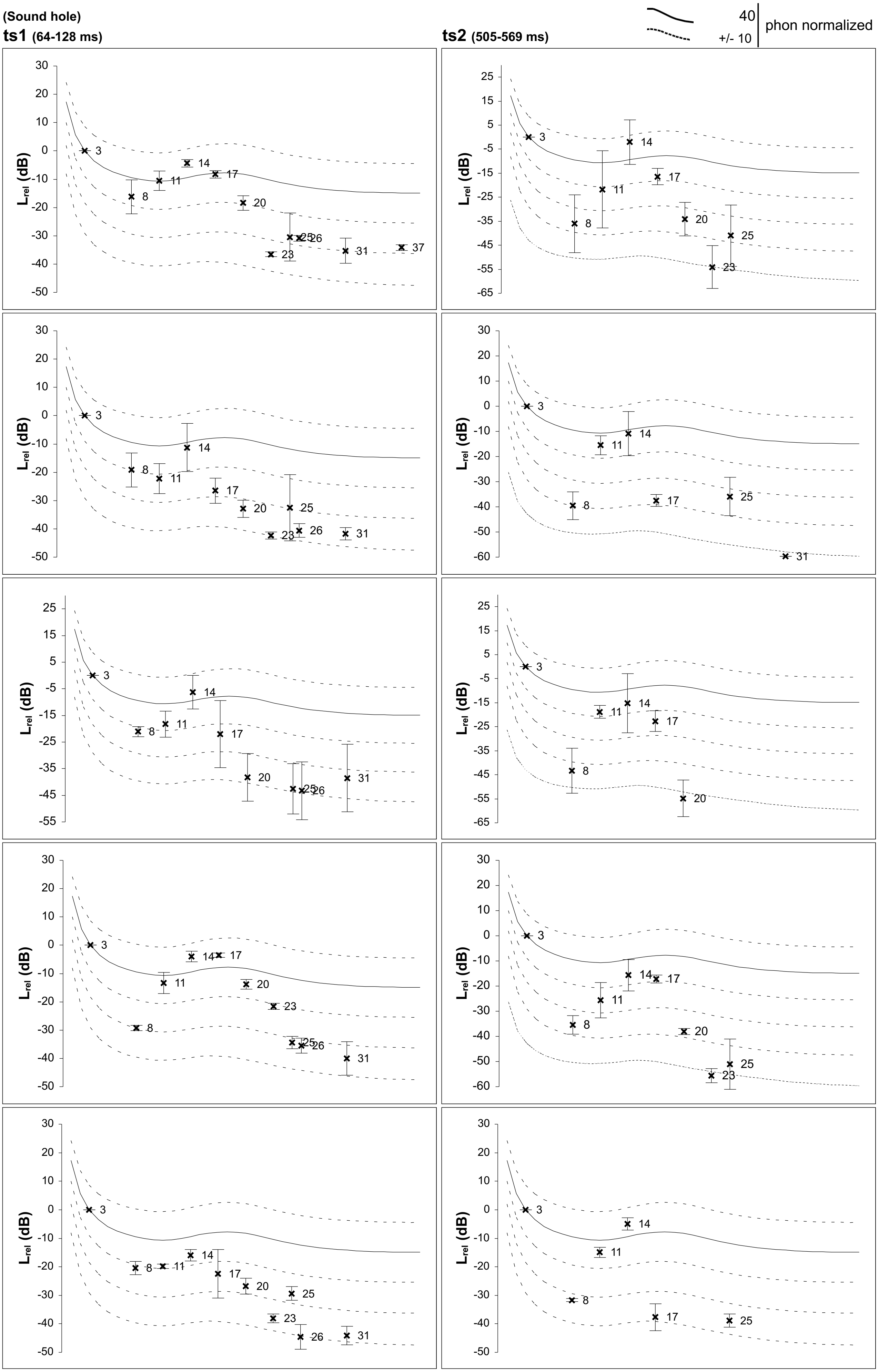
G1

G2

G3

G4

G5

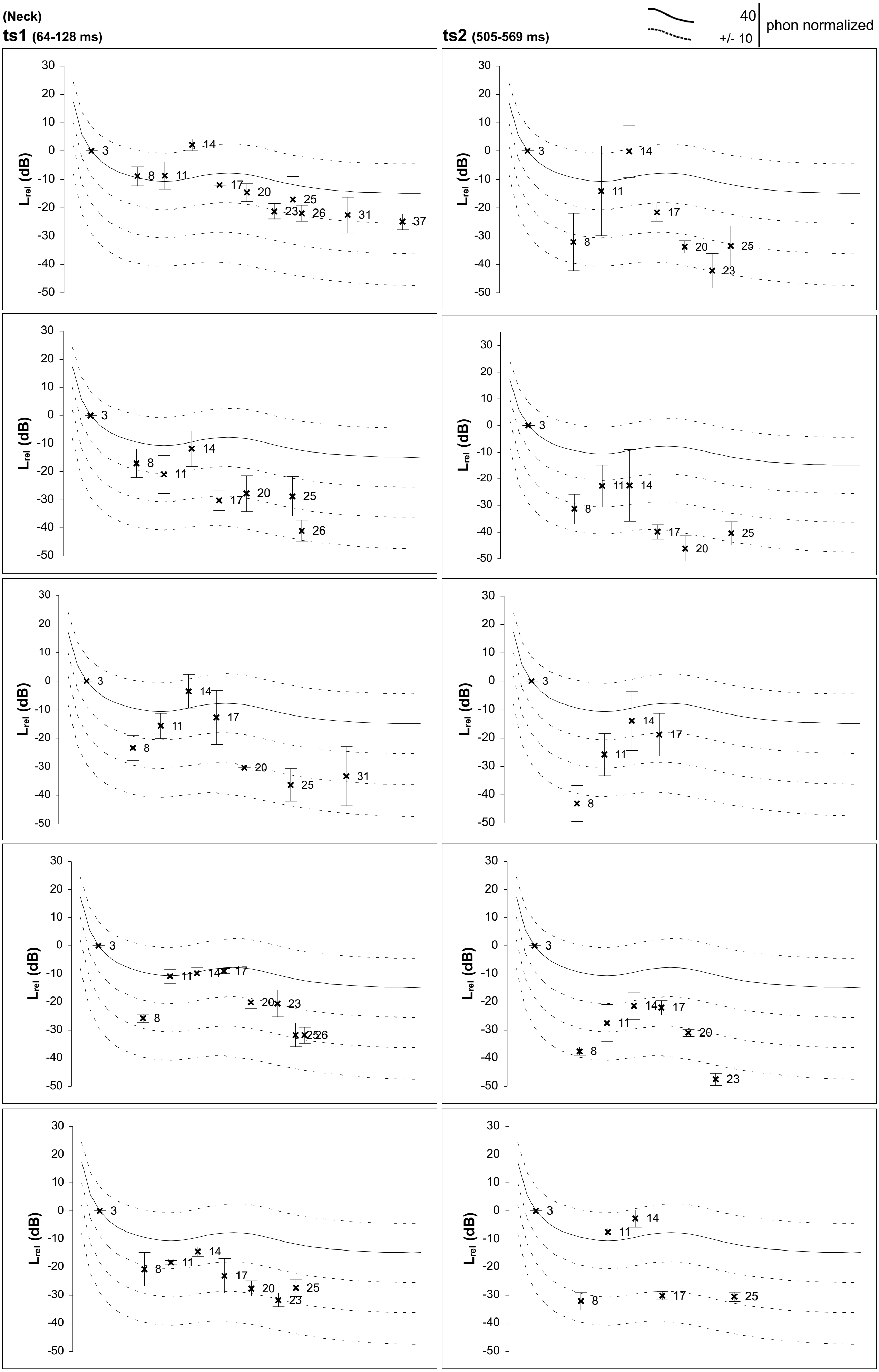


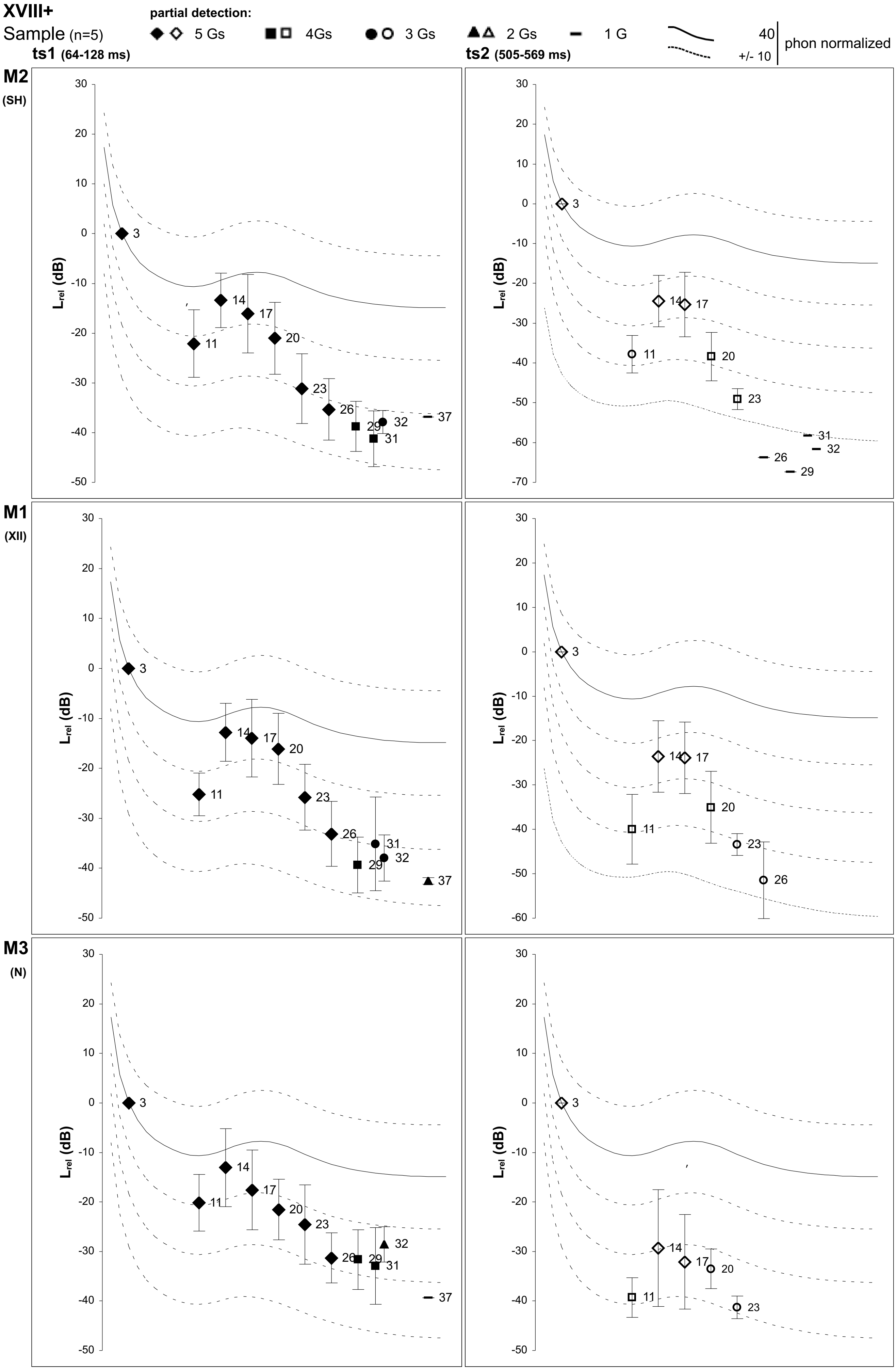
XVIII

M3 (Neck)

ts1 (64-128 ms) **ts2** (505-569 ms)

G1 G2 G3 G4 G5




XVIII+
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
Lrel (dB)

XVIII+

M1 (XII)

ts1 (64-128 ms) **ts2** (505-569 ms)

40 | +/- 10 | phon normalized

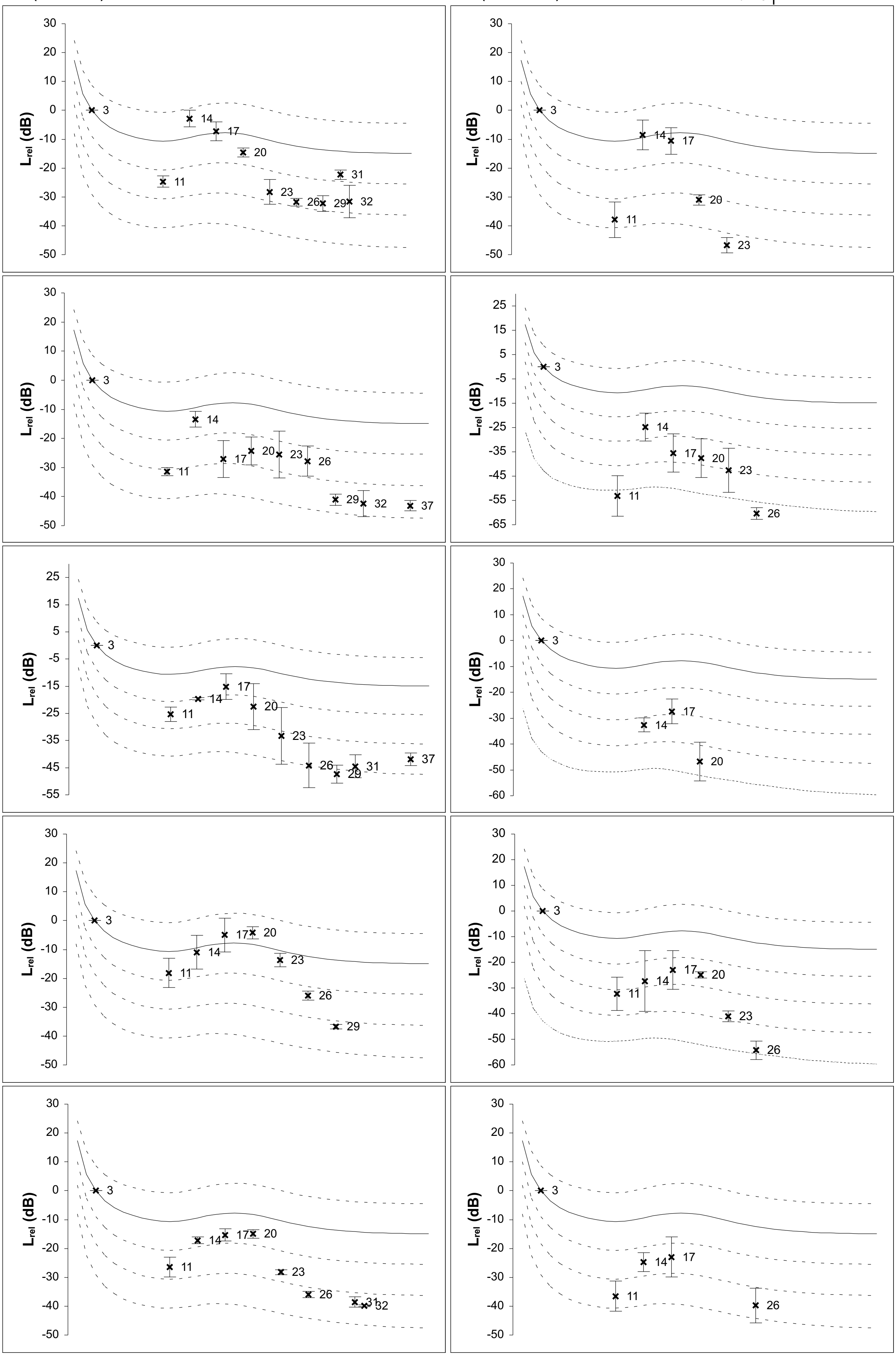
G1

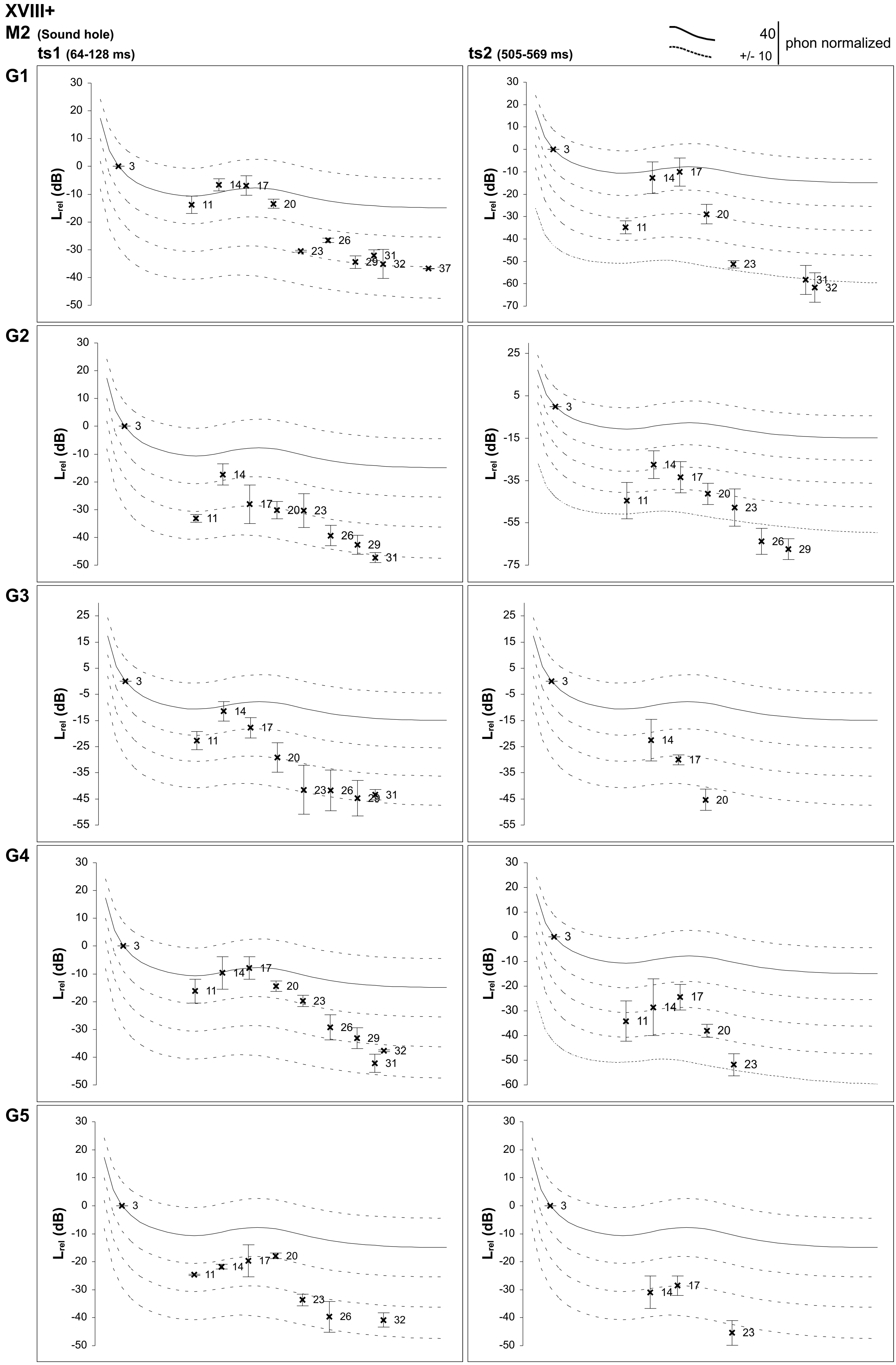
G2

G3

G4

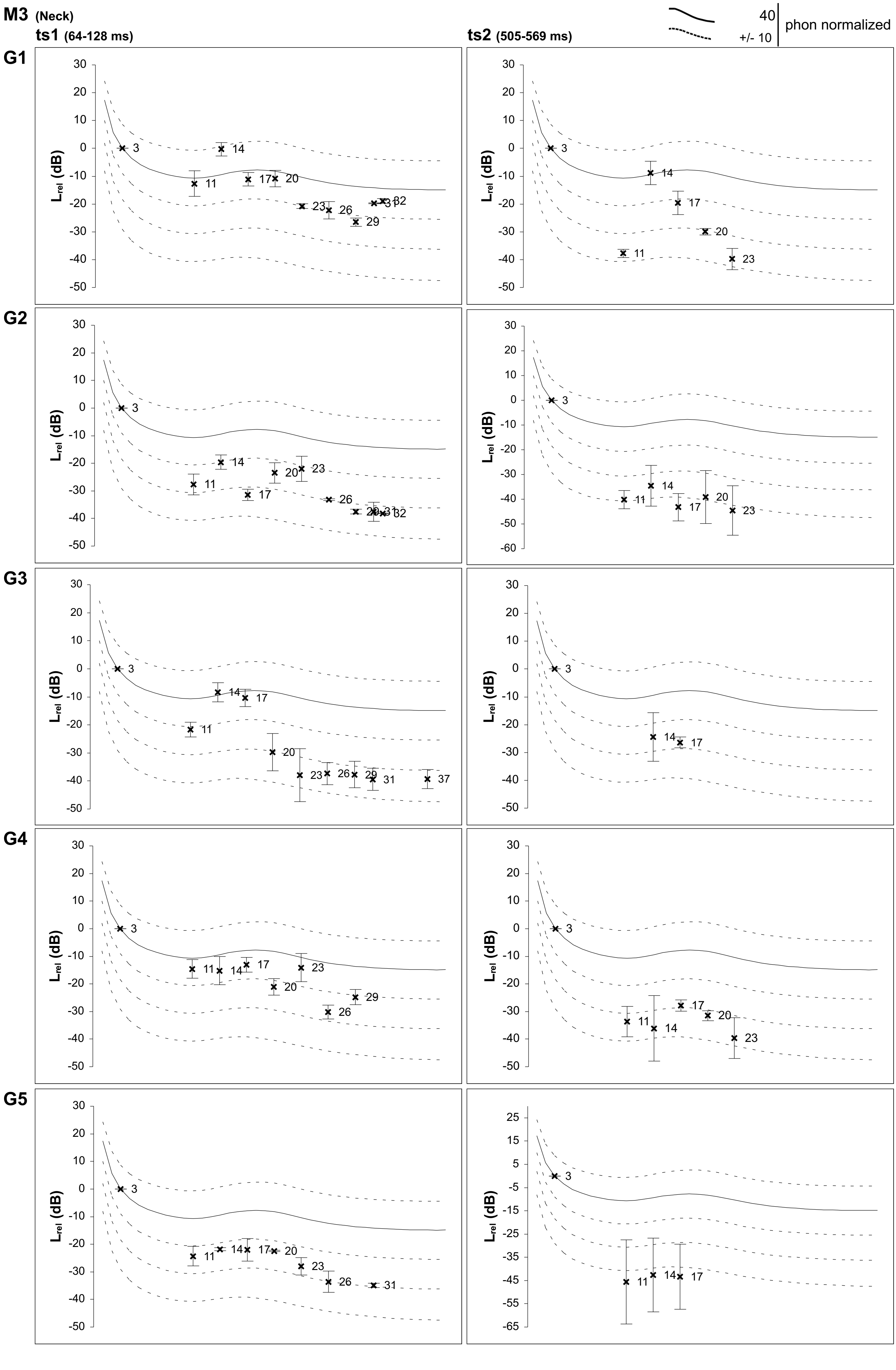
G5

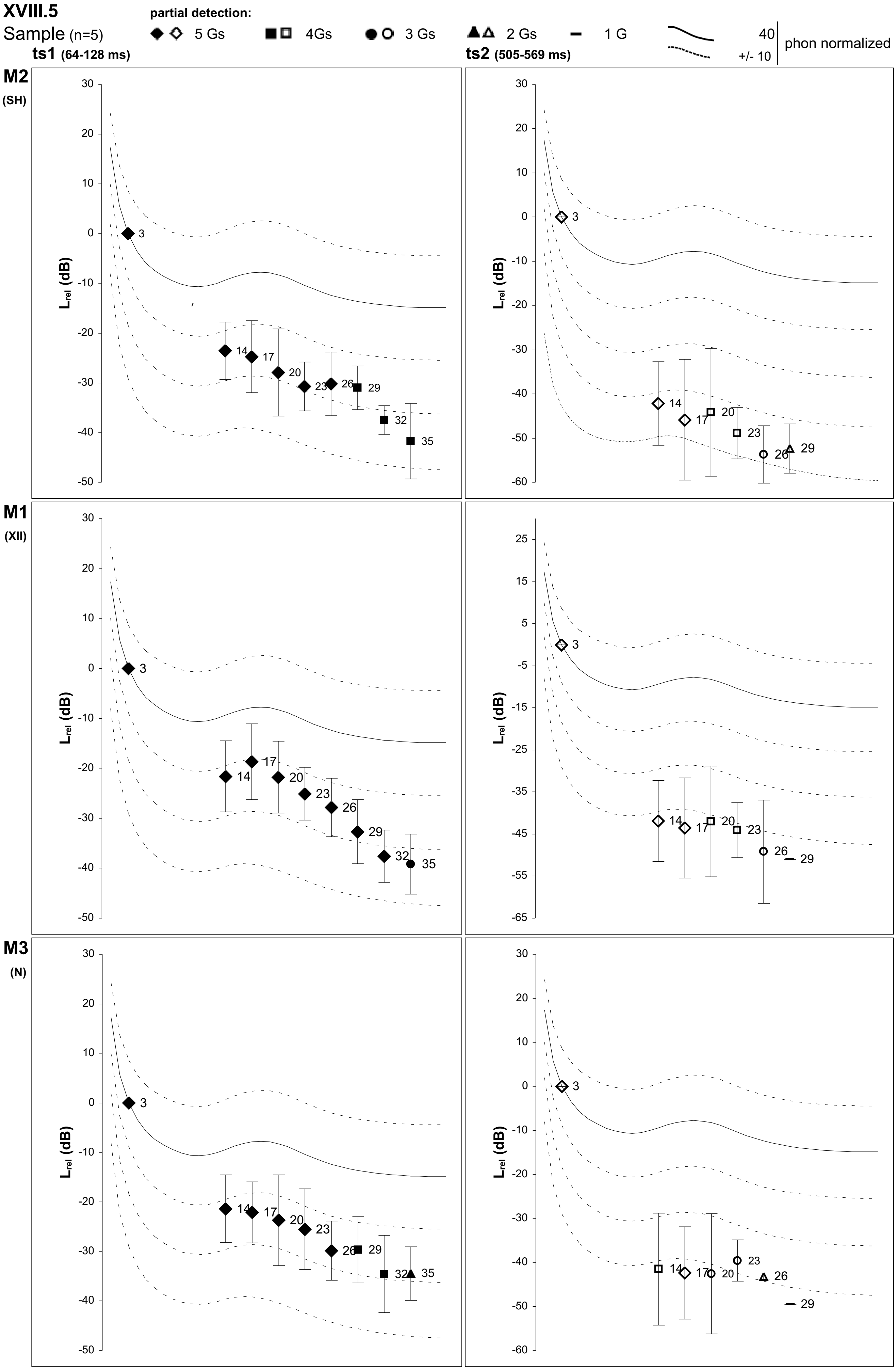



XVIII+
M2 (Sound hole)
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
Lrel (dB)

XVIII+

M3 (Neck)

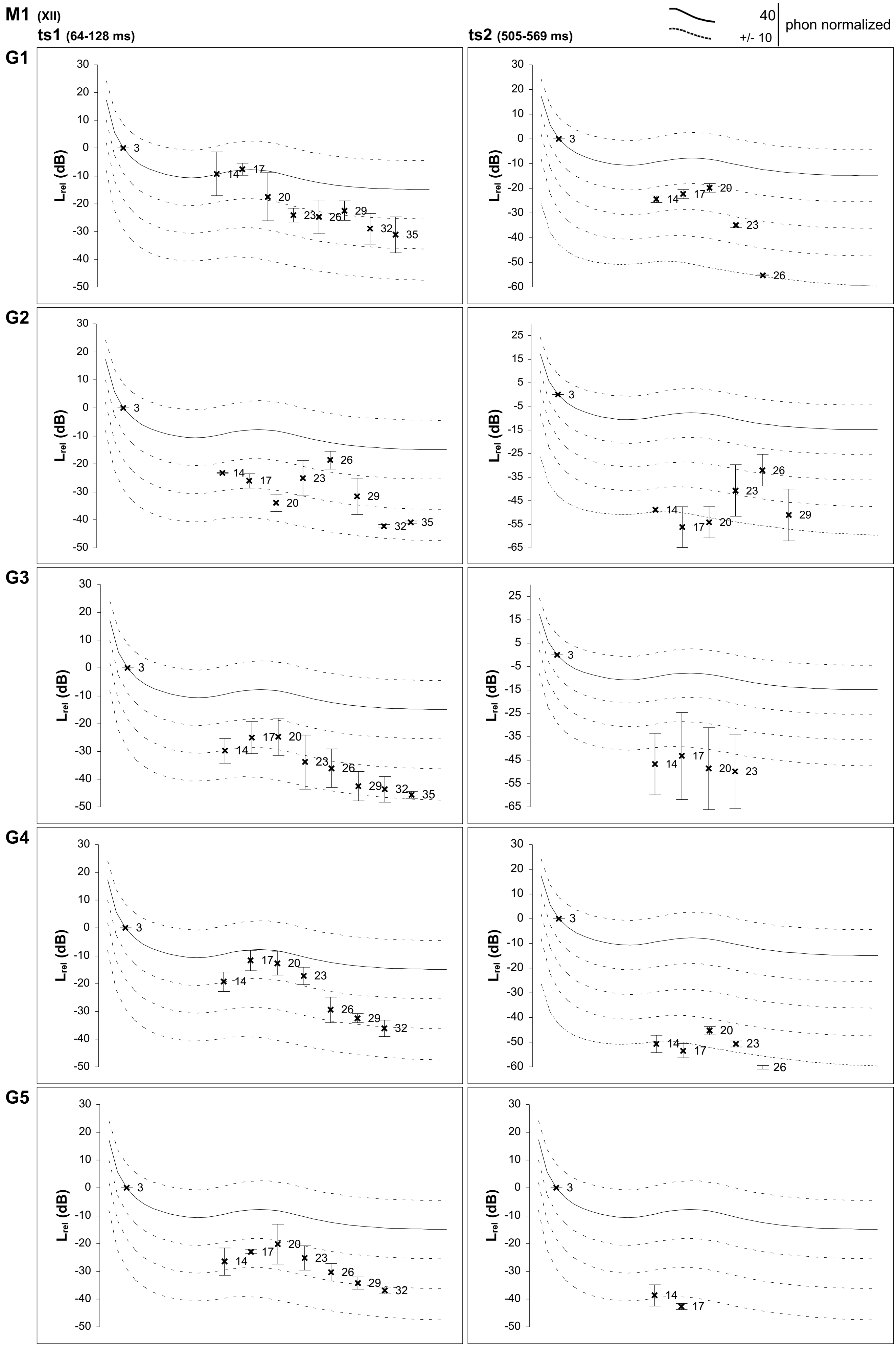




XVIII.5
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2 (SH)
M1 (XII)
M3 (N)
L_rel (dB)

XVIII.5

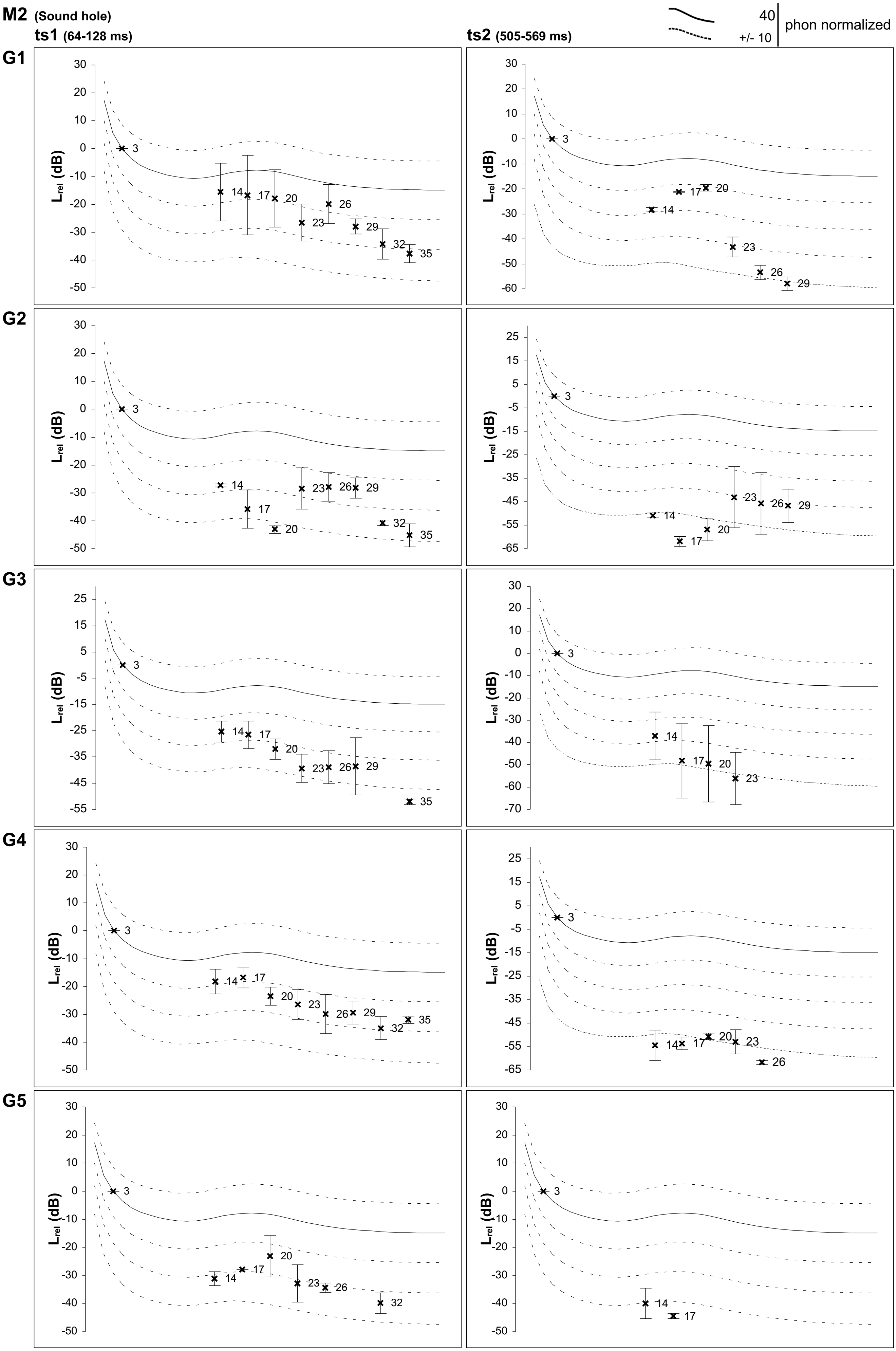
M1 (XII)



XVIII.5

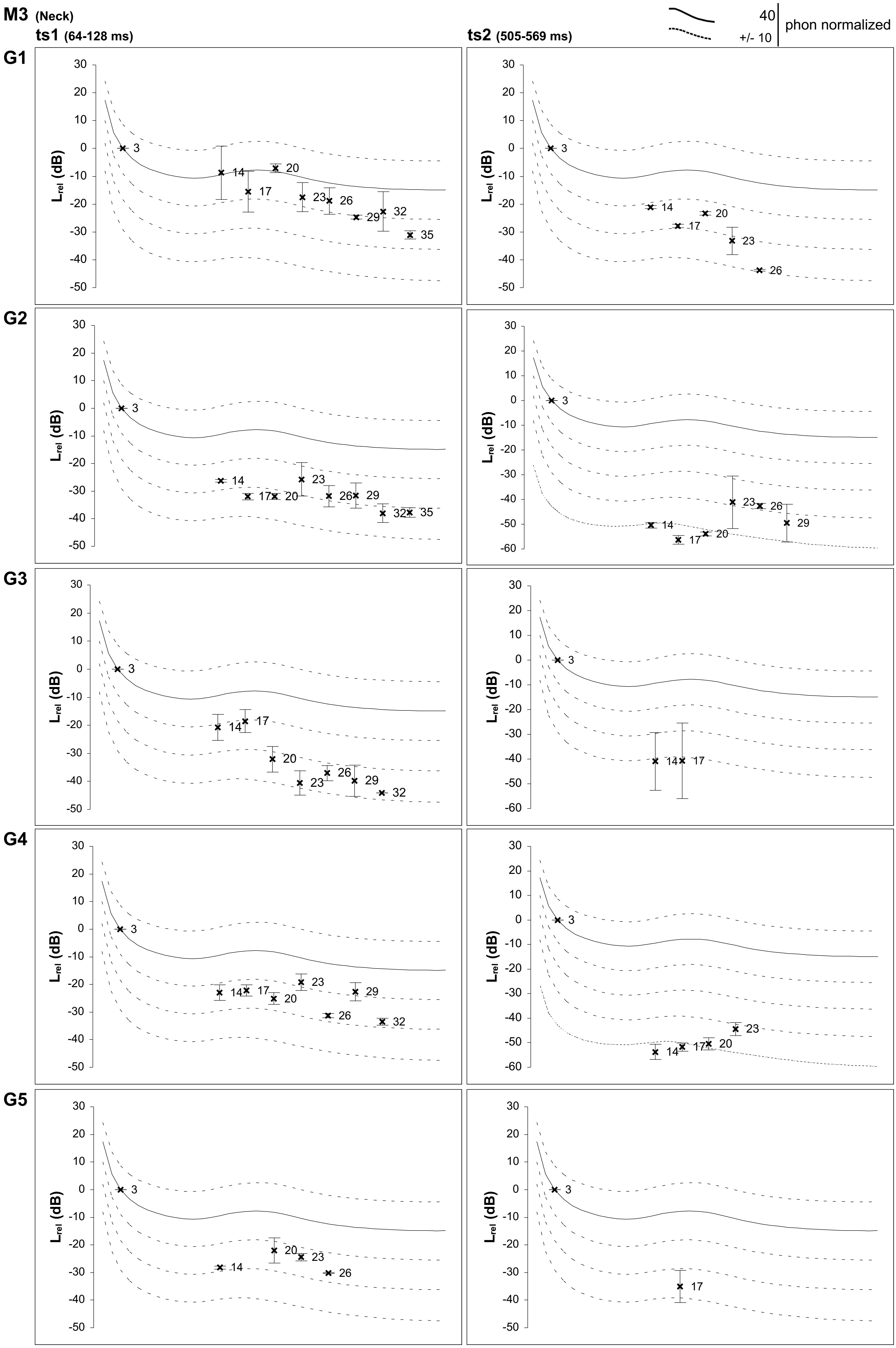
M2 (Sound hole)

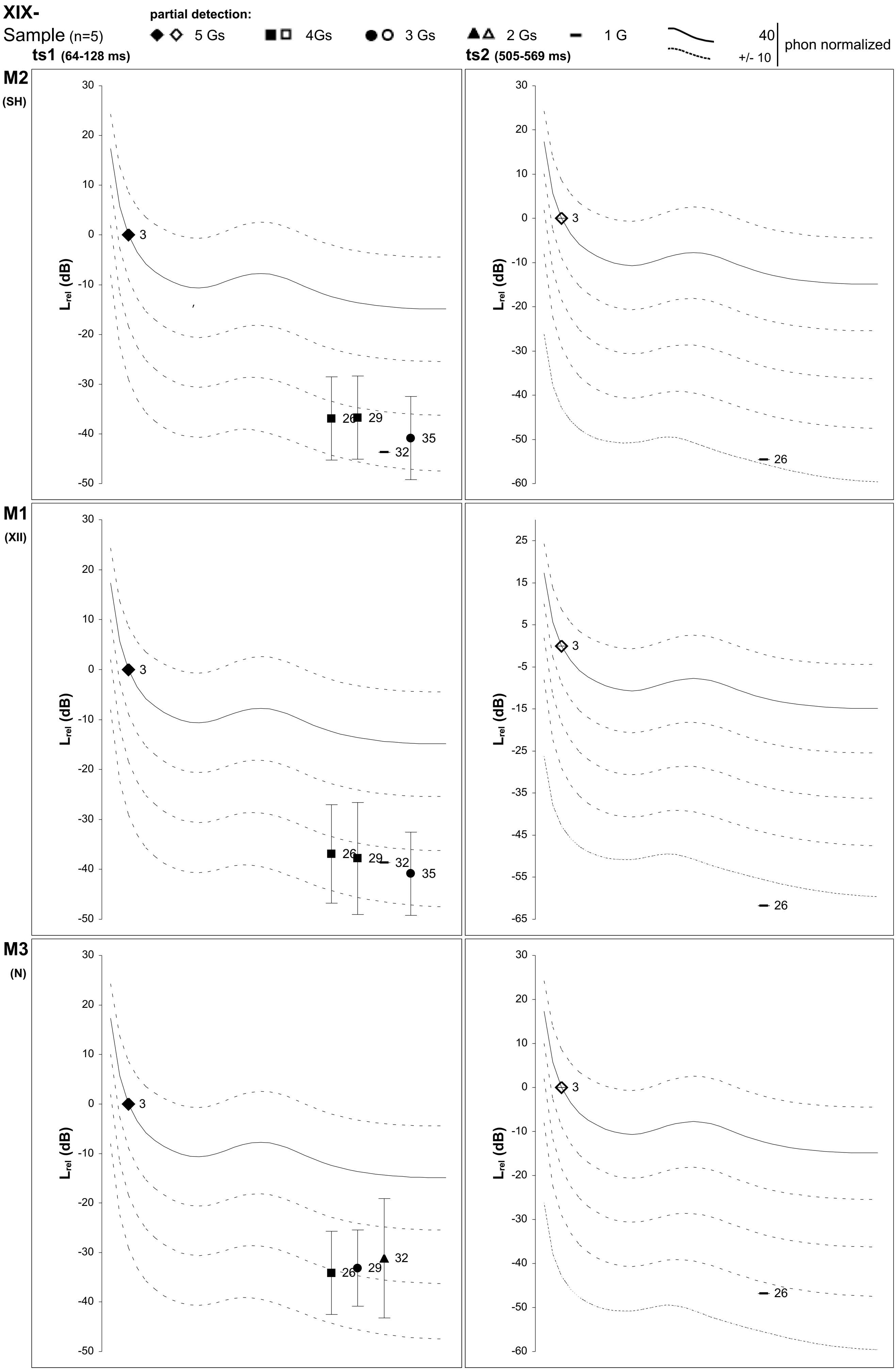
ts1 (64-128 ms) **ts2** (505-569 ms)



XVIII.5

M3 (Neck)




XIX-
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_rel (dB)
3
26
29
32
35

XIX-
M1 (XII)

40 | +/- 10 — phon normalized

ts1 (64-128 ms) **ts2** (505-569 ms)

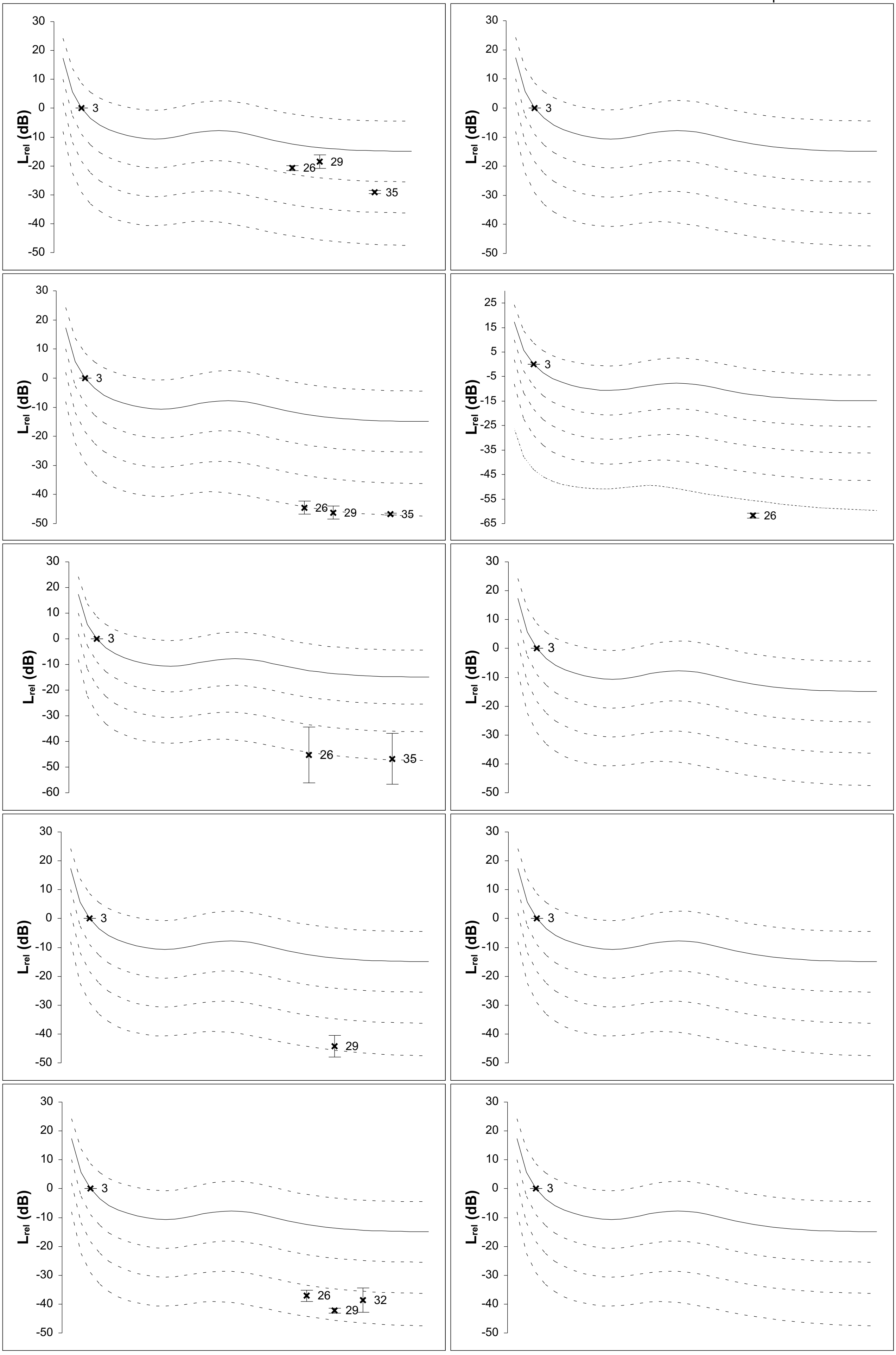
G1 (2Ts)

G2

G3

G4

G5



XIX-

M2 **(Sound hole)**

ts1 **(64-128 ms)** **ts2** **(505-569 ms)**

40 / +/- 10 phon normalized

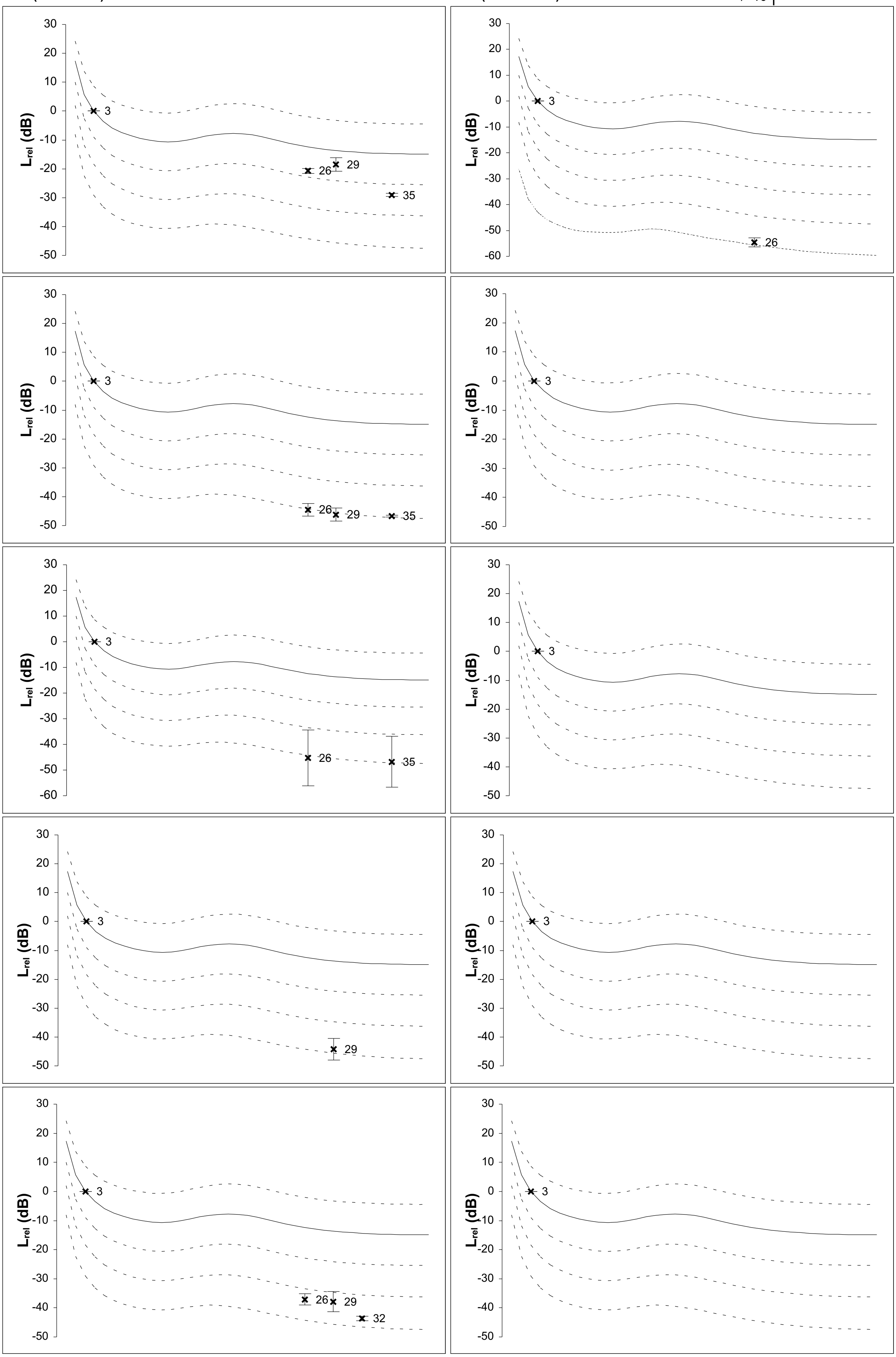
G1 (2Ts) (2Ts)

G2

G3

G4

G5

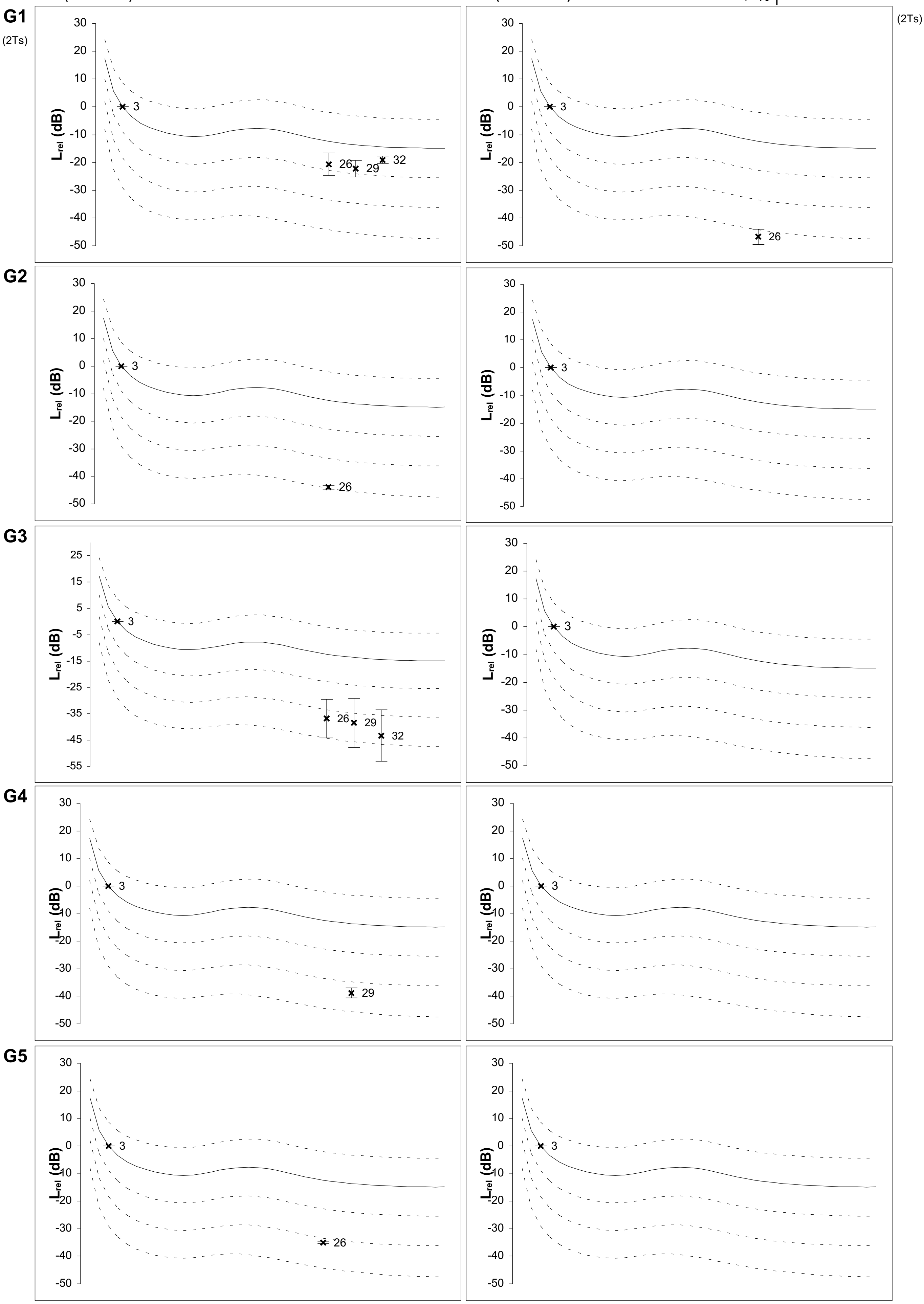


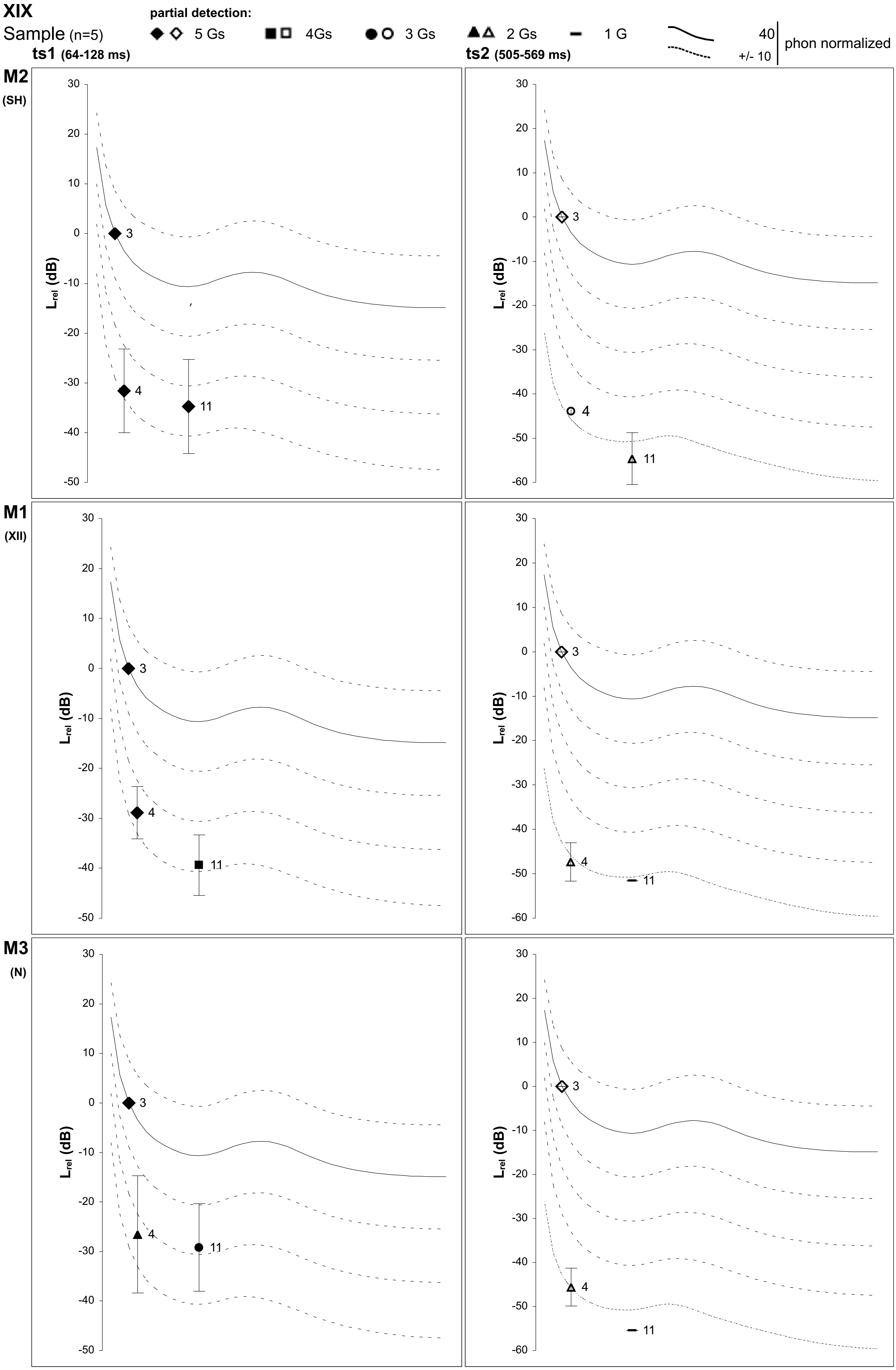
XIX-

M3 **(Neck)**

ts1 **(64-128 ms)** **ts2** **(505-569 ms)**

40 / +/- 10 phon normalized




XIX
Sample (n=5)
partial detection:
5 Gs
4Gs
3 Gs
2 Gs
1 G
40
+/- 10
phon normalized
ts1 (64-128 ms)
ts2 (505-569 ms)
M2
(SH)
M1
(XII)
M3
(N)
L_{rel} (dB)
30
20
10
0
-10
-20
-30
-40
-50
-60
3
4
11

XIX

M1 (XII)

40 / +/- 10 phon normalized

ts1 (64-128 ms) **ts2** (505-569 ms)

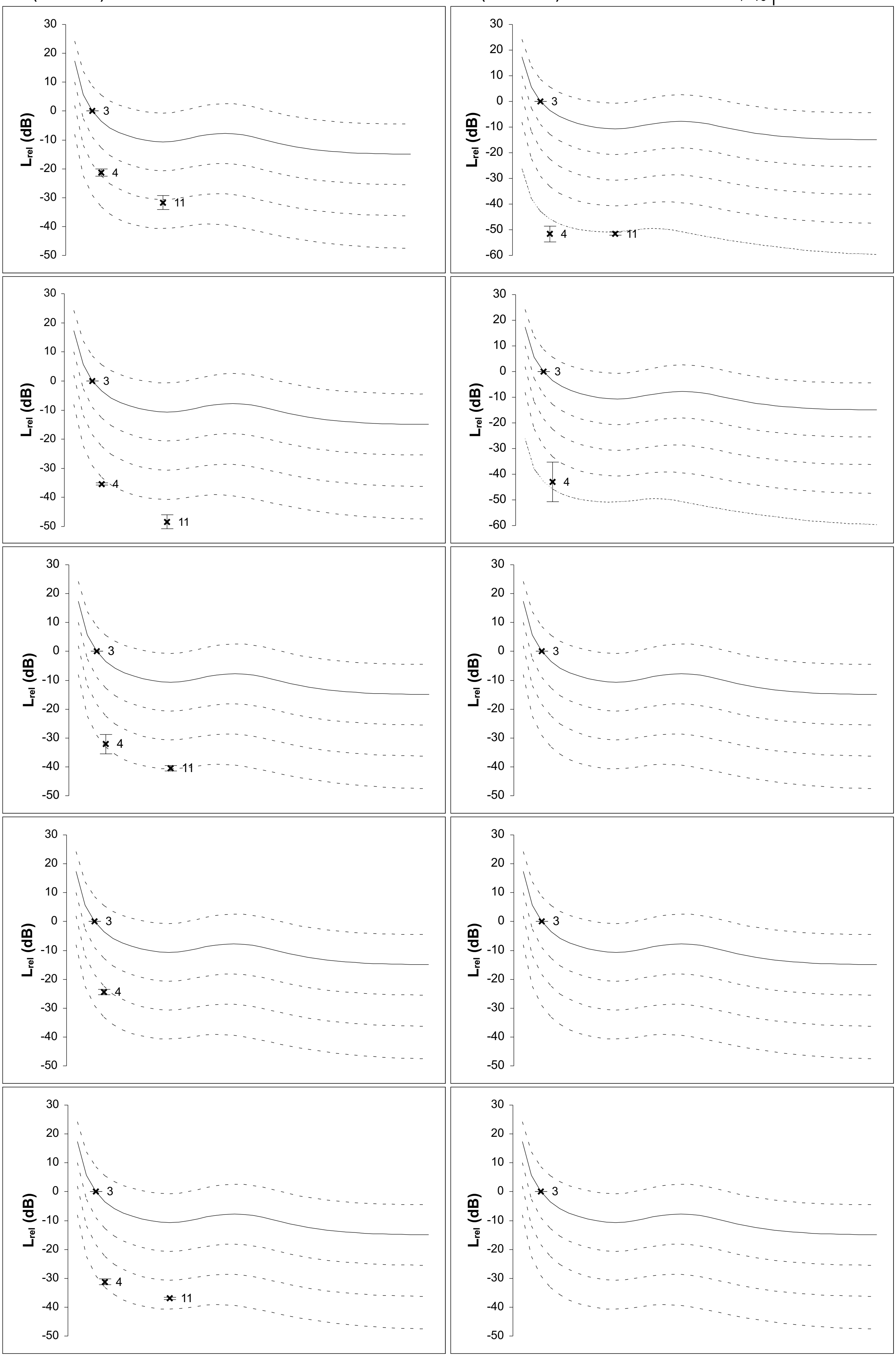
G1

G2

G3

G4

G5

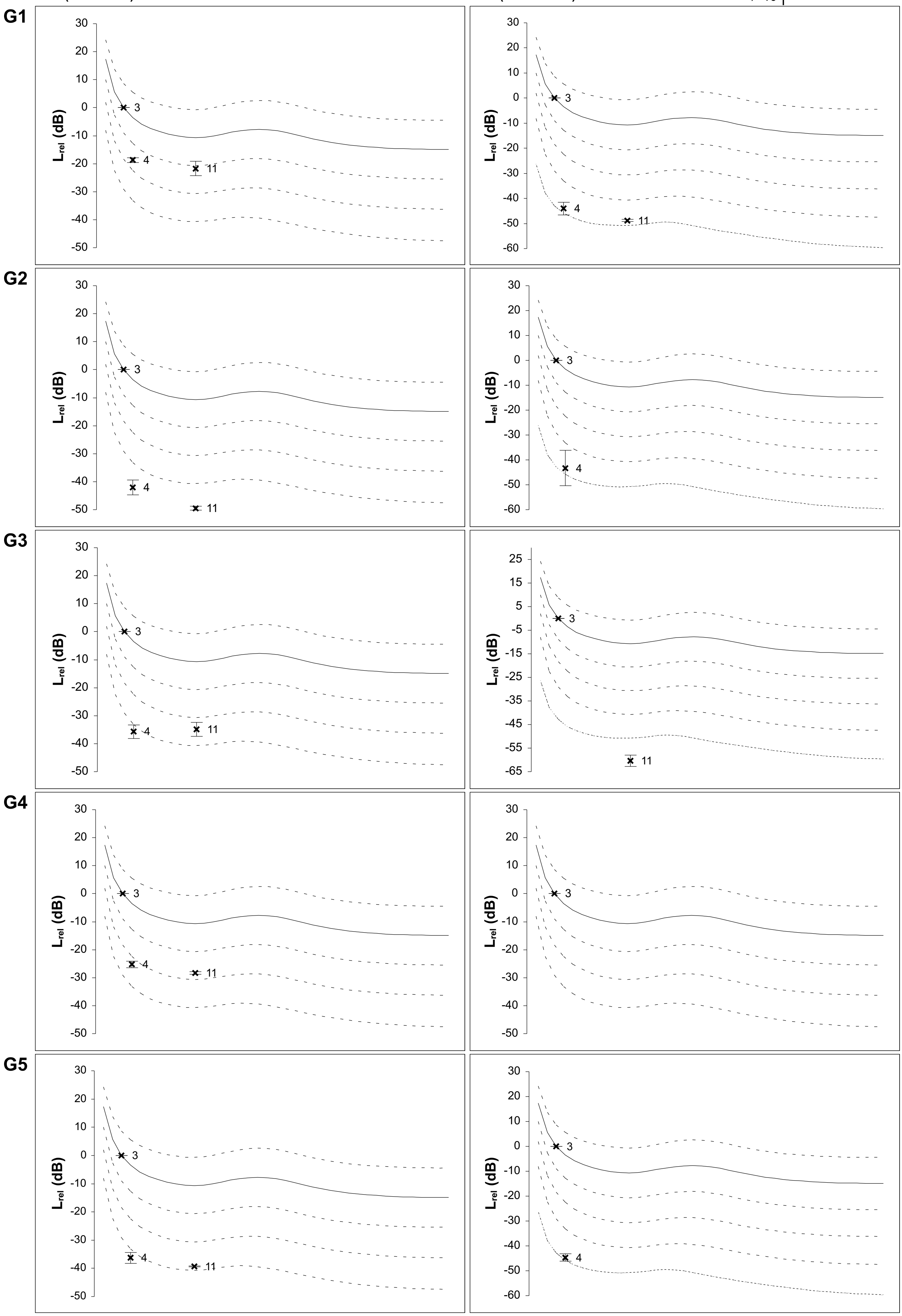


XIX

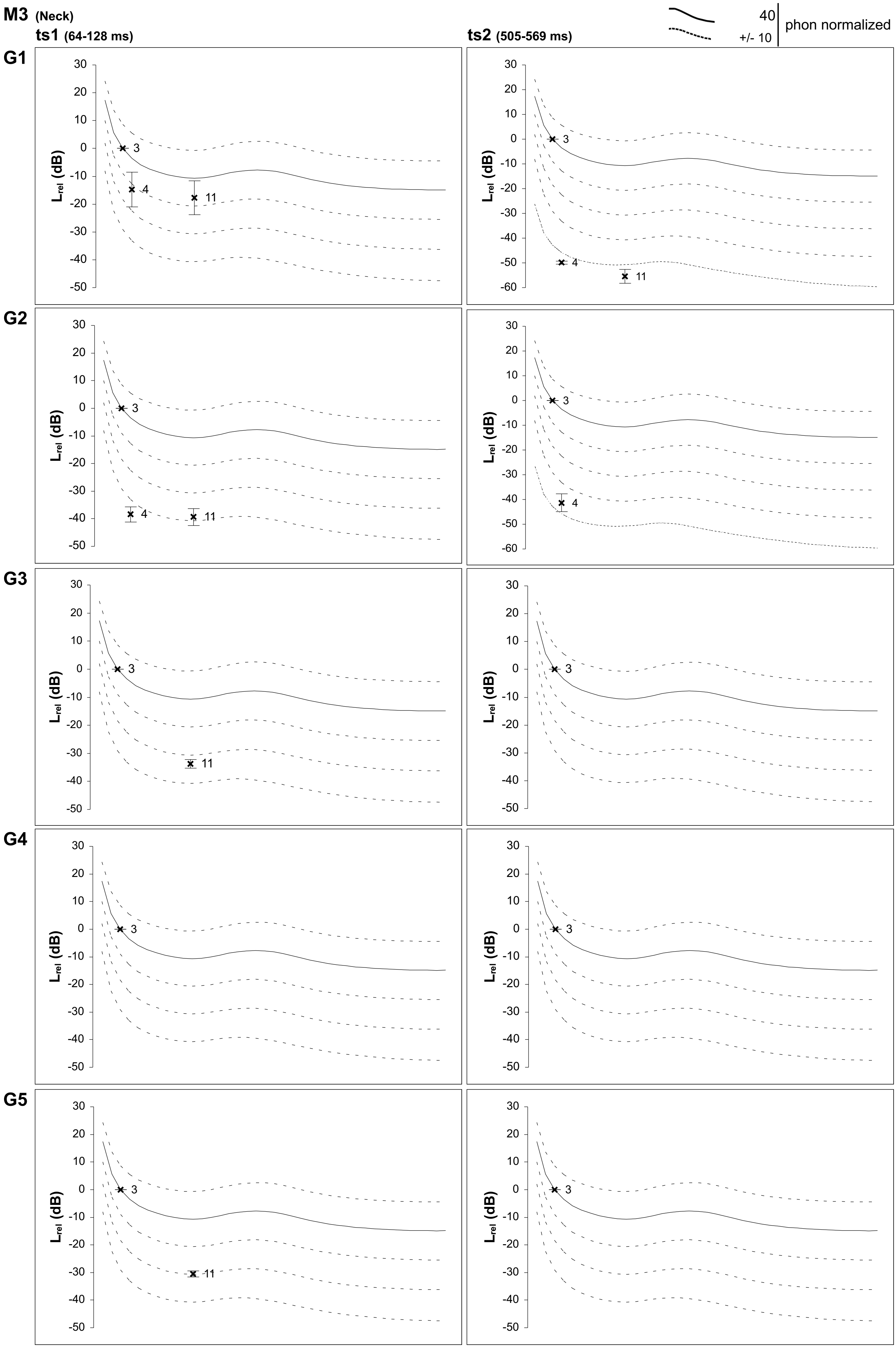
M2 (Sound hole)

ts1 (64-128 ms) **ts2** (505-569 ms)

40 / +/- 10 phon normalized



XIX


M3 (Neck)
ts1 (64-128 ms)
ts2 (505-569 ms)
40
+/- 10
phon normalized
G1
G2
G3
G4
G5
L_{rel} (dB)
3
4
11

Part 2

Rita Torres

The fireflies, twinkling among leaves, make the stars wonder

for amplified guitar and live electronics

(2015)

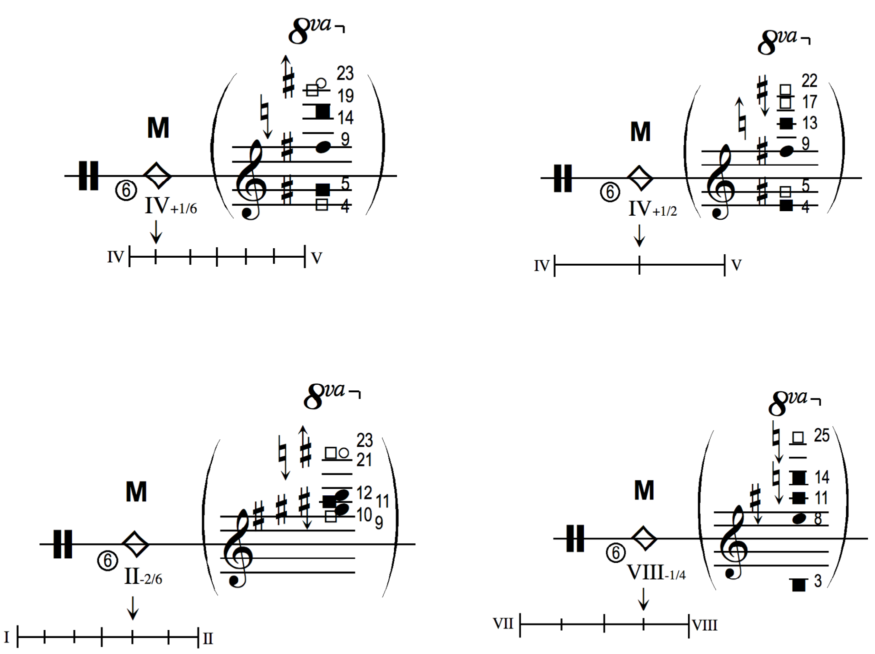
PERFORMANCE INSTRUCTIONS

Guitar & Trigger

A (worn) **plectrum** is necessary to strike the strings and to rub them with *tremolato* (ca. 12 attacks/beat; with a side of the plectrum) while muting the strings at around fret XIII. When striking the strings, damp the soundboard with the wrist (a long sleeve or a sock are useful to slide the wrist) and use a dead stroke (i.e. the plectrum remains on the string after striking) except when another sound rapidly follows. A **pedal** is used to trigger the sampling of the sounds that result from striking the string, and is notated with a grace note with a squared note head. Except for locations at frets, there is a certain degree of freedom in the locations at which the strings are struck/rubbed. These are:

- *s.* [fret number] (abbreviation for *sul C.* ...): at fret ...
- *s.b.t. (sulla buca, tasto)*: halfway between fret XIX and the middle of the sound hole
- *s.b. (sulla buca)*: at the middle of the sound hole
- *s.b.r. (sulla buca, rosetta)*: halfway between the middle of the sound hole and the rosette
- *s.r. (sulla rosetta)*: at the rosette
- *p.s.p. (poco sul ponticello)*: at ca. 3 cm from the rosette on the saddle side

With **multiphonics (M)** a sound arises more rich in colour than with harmonics. The partial(s) of the open-string sound that name the pitch(es) that may be perceived is/are notated in parentheses with their number(s) and pitch(es) in the guitar transposition. Their approximate relative loudness at the position of the microphone (see below) is differentiated by different note heads. The corresponding loudness scale in decreasing order is: black square > black circle > white square > white circle. When only one or a few pitches are notated, the desired sound is the sound with that/those pitch(es) that results after the rapid decay of the other pitches. There are two degrees for the touch pressure: (1) very light, which is notated simply by an asterisk after the M and is lighter than (2) the usual harmonics pressure, which in this scale is considered to be light and is used in the absence of an asterisk after the M. Both these pressures are stronger than the extremely light pressure with which the fundamental of the open-string sound is perceived at locations between fret III and XIX. Except when otherwise stated, use always a very short touch duration, instead of the short duration of harmonics. Think of the touch locations between frets as equidistant *virtual frets* resulting from the subdivision of the space between two consecutive frets in the number of parts indicated by the denominator of the fraction after the fret number; the fraction's numerator and the plus or minus sign indicate at which *virtual fret* to touch. Examples:



Amplification & Trigger

The sounds produced by rubbing and striking are amplified by a condenser microphone as close as possible to the guitar body (M_B), and are projected in the front part of the room. The sounds of multiphonics are amplified by a condenser microphone in front of fret XII at a distance of ca. 30 cm (M_{XII}; make sure the proximity effect is eliminated), and are projected in all loudspeakers. The trigger is used to change and stop the patterns explained below.

Electronics

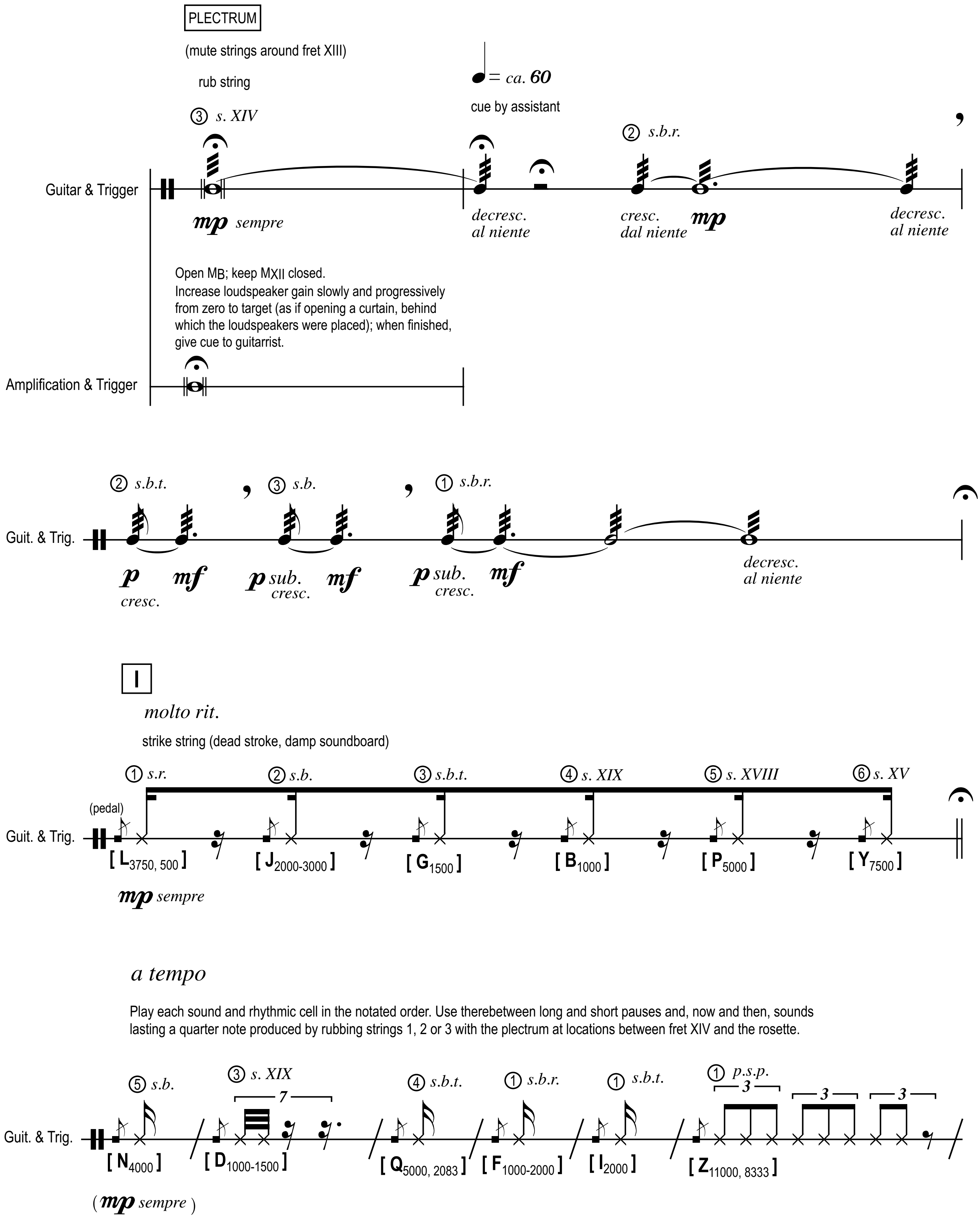
The single sounds and rhythmic cells that are produced by striking the strings, which are marked in square brackets with the letters A to Z, are sampled and immediately played back repeatedly, being projected in the front part of the room. The (in some cases variable) time interval with which the sounds are repeated is indicated in milliseconds in the (first element of the) letter's subscript, and relates to the beginning of the cell. Five of the patterns (letters L, Q, U, X, and Z; on strings 1, 2 and 4) are changed in section II, by adding to the end of the cell a sample of its attack, using the time interval in the second element of the letter's subscript, which relates to the beginning of the cell. In section III, this addition is replaced by the sample of one attack chosen randomly among those at strings 5 and 6 (letters A, C, H, M, N, P, R, V, Y). All additions are projected with a slightly softer loudness in the back of the room. The playback of the changed patterns stop first, then stop the rest of the patterns on strings 1 to 4, and finally those at strings 5 and 6, all randomly at random intervals between 1 and 5 seconds.

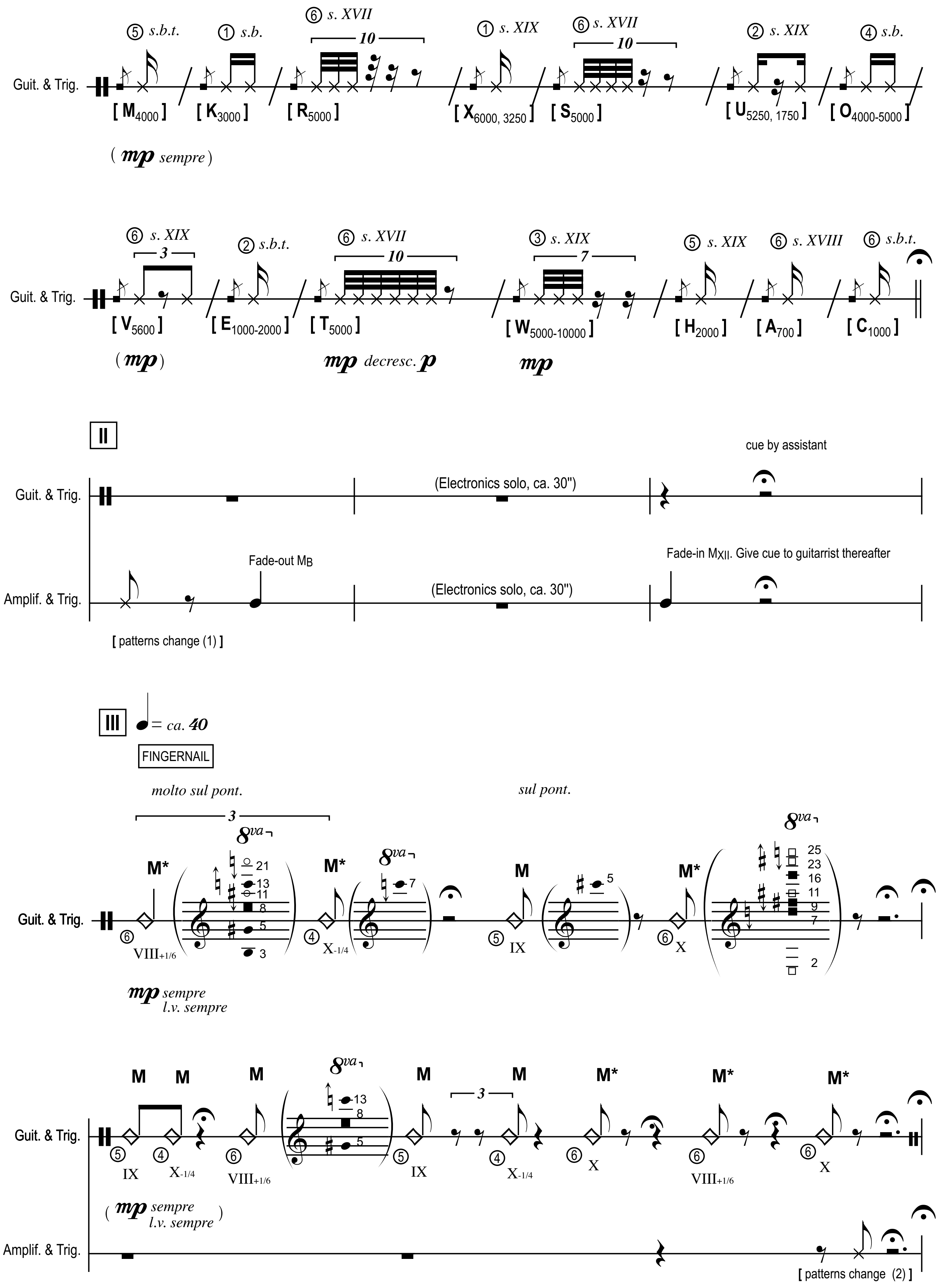
The fireflies, twinkling among leaves, make the stars wonder

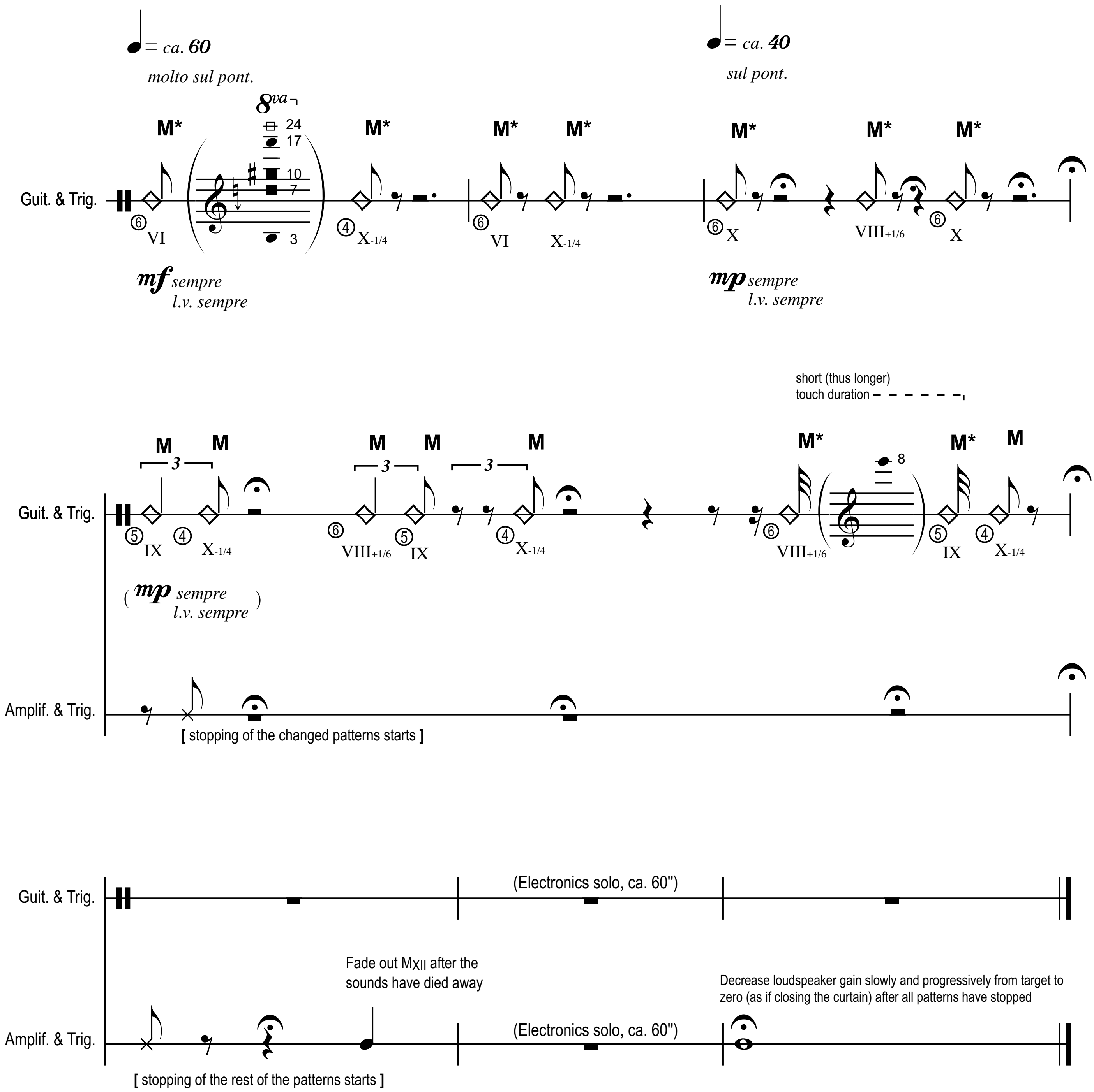
to Francisco Huguet

DRAFT VERSION

Rita Torres
(2015)




Guit. & Trig.
5 s.b.t.
1 s.b.
6 s. XVII
10
1 s. XIX
6 s. XVII
2 s. XIX
4 s.b.
[M4000] [K3000] [R5000] [X6000, 3250] [S5000] [U5250, 1750] [O4000-5000]
(mp sempre)
6 s. XIX
3
2 s.b.t.
6 s. XVII
3 s. XIX
7
5 s. XIX
6 s. XVIII
6 s.b.t.
[V5600] [E1000-2000] [T5000] [W5000-10000] [H2000] [A700] [C1000]
(mp)
mp decresc. p
mp
II
cue by assistant
(Electronics solo, ca. 30")
Amplif. & Trig.
Fade-out MB
Fade-in MXII. Give cue to guitarrist thereafter
[patterns change (1)]
III
= ca. 40
FINGERNAIL
molto sul pont.
sul pont.
8va
M*
M
VIII+1/6
X-1/4
IX
X
mp sempre
l.v. sempre
(mp sempre l.v. sempre)
[patterns change (2)]


= ca. 60
molto sul pont.
8va
M*
Guit. & Trig.
VI
X-1/4
mf sempre
l.v. sempre
= ca. 40
sul pont.
mp sempre
l.v. sempre
VIII+1/6
short (thus longer)
touch duration
M
IX
(mp sempre
l.v. sempre)
Amplif. & Trig.
[stopping of the changed patterns starts]
(Electronics solo, ca. 60")
Fade out MXII after the
sounds have died away
Decrease loudspeaker gain slowly and progressively from target to
zero (as if closing the curtain) after all patterns have stopped
[stopping of the rest of the patterns starts]

Rita Torres

Si amanece, nos vamos

for guitar

(2015)

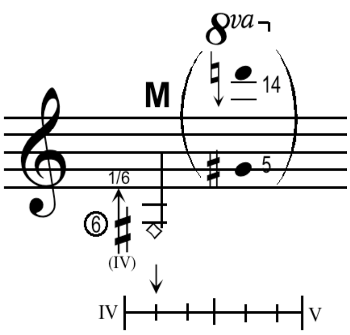
PERFORMANCE INSTRUCTIONS

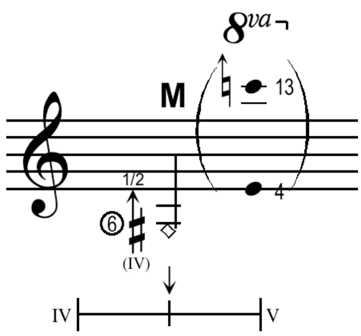
This piece is to be performed in a small or medium-sized room appropriate for a guitar recital.

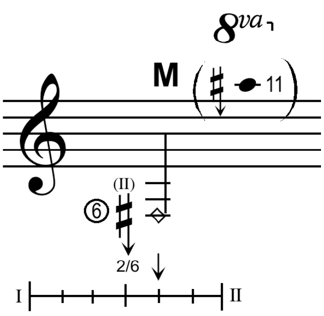
The **tremolati** are all measured, of about 12 attacks per beat. When notated with an accent, accentuated all attacks.
The hand needs constantly to slide – it is useful to use scotch tape or a sock on the lower hand palm.

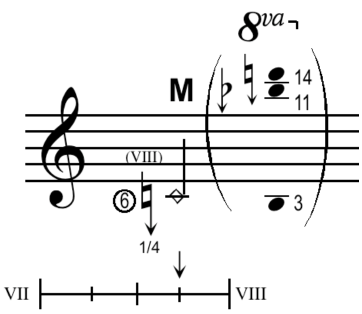
A **plectrum** is necessary throughout most of the piece, always to pluck the string, held at an angle with the string of less than 45º. Its orientation (i.e. when plucking dowards: towards the bridge or towards the soundhole) should be that which causes less noise (this appears to depend on the direction of the wounding inclination).

With **multiphonics (M)**, a sound arises more rich in colour than with harmonics. The partial(s) of the open-string sound that name the loudest pitches that may be perceived is/are notated in parentheses with their number(s) and pitch(es) in the guitar transposition. There are two degrees, up to which the touch pressure increases: extremely light and very light, both lighter than the usual harmonics pressure, which in this scale is considered to be light. When the sounds are left to vibrate, use a very short touch duration, instead of the short duration of harmonics. Think of the touch locations between frets as equidistant *virtual frets* resulting from the subdivision of the space between two consecutive frets in the number of parts indicated by the denominator of the fraction above/below the accidental; the fraction's numerator and the accidental's arrow indicate at which *virtual fret* to touch. The fret corresponding to the semitonic accidental is in parentheses. Examples:





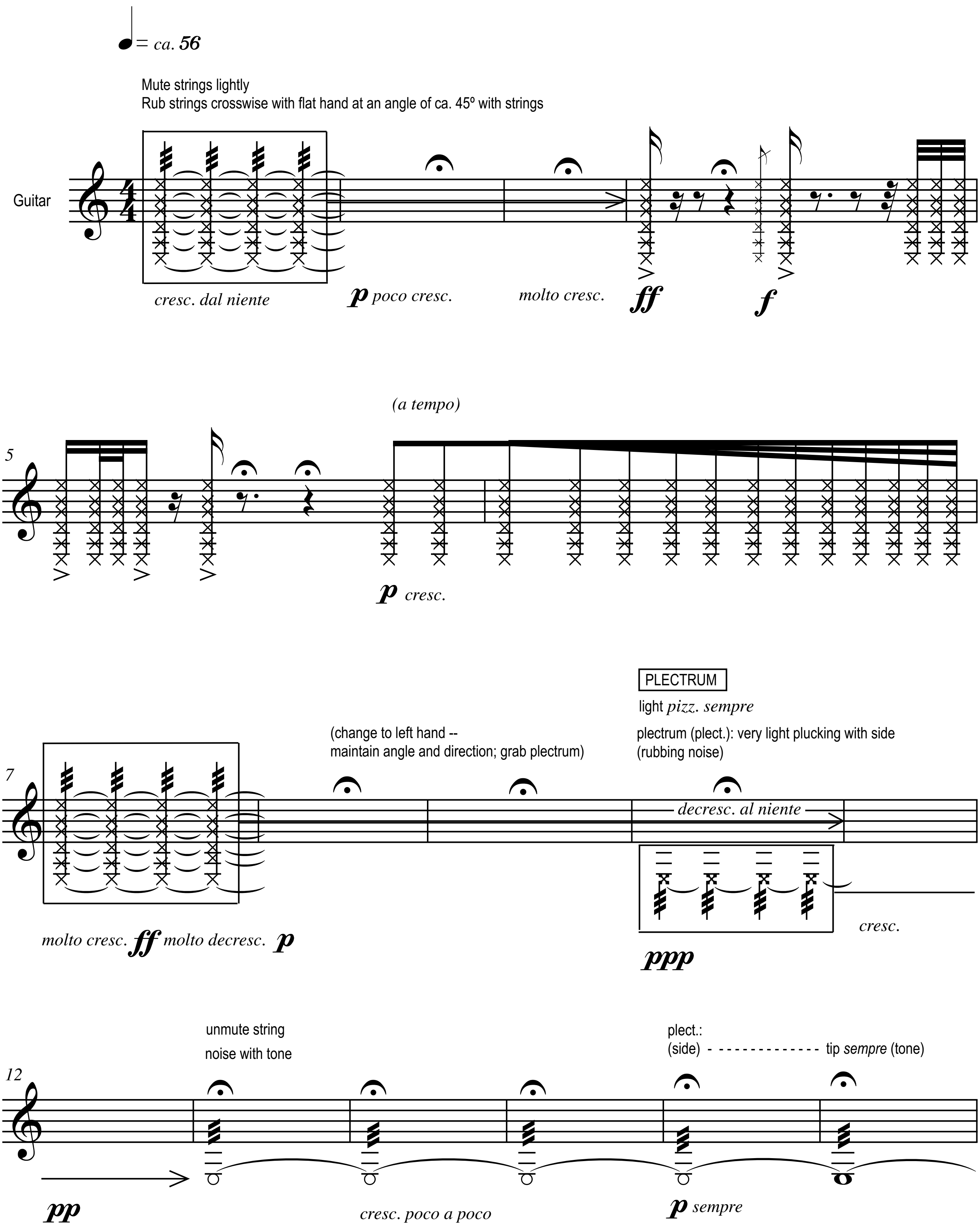


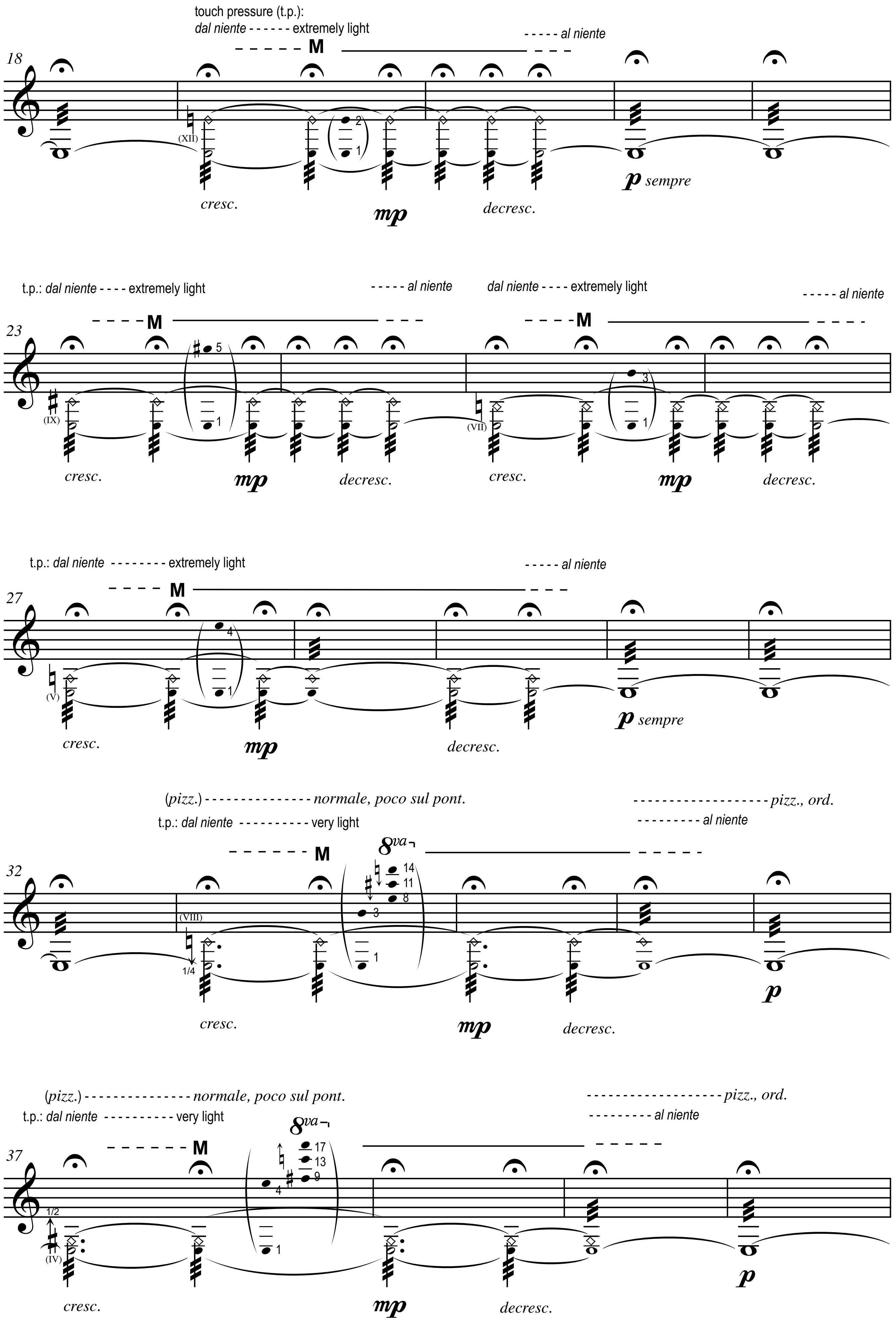


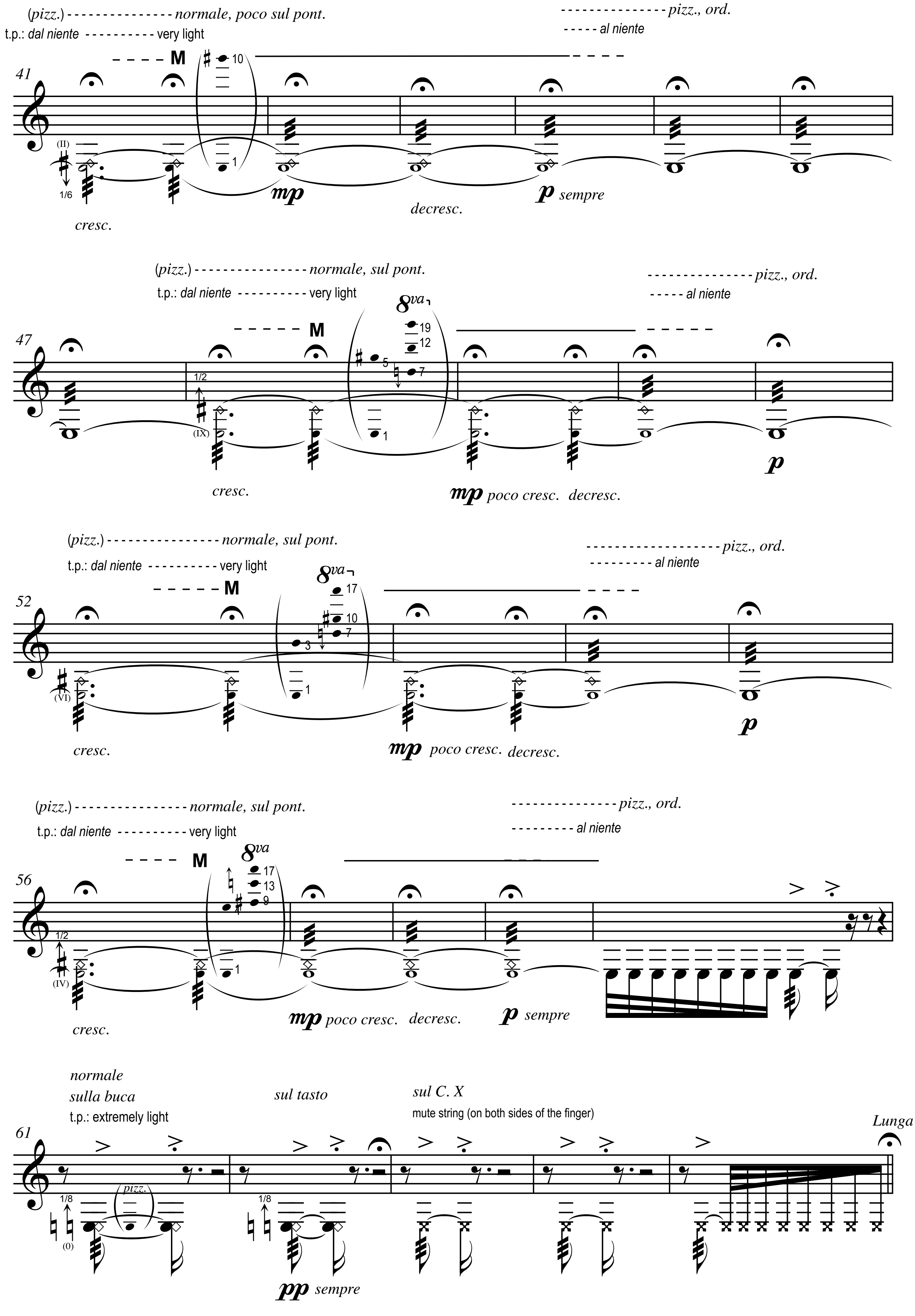
Si amanece, nos vamos

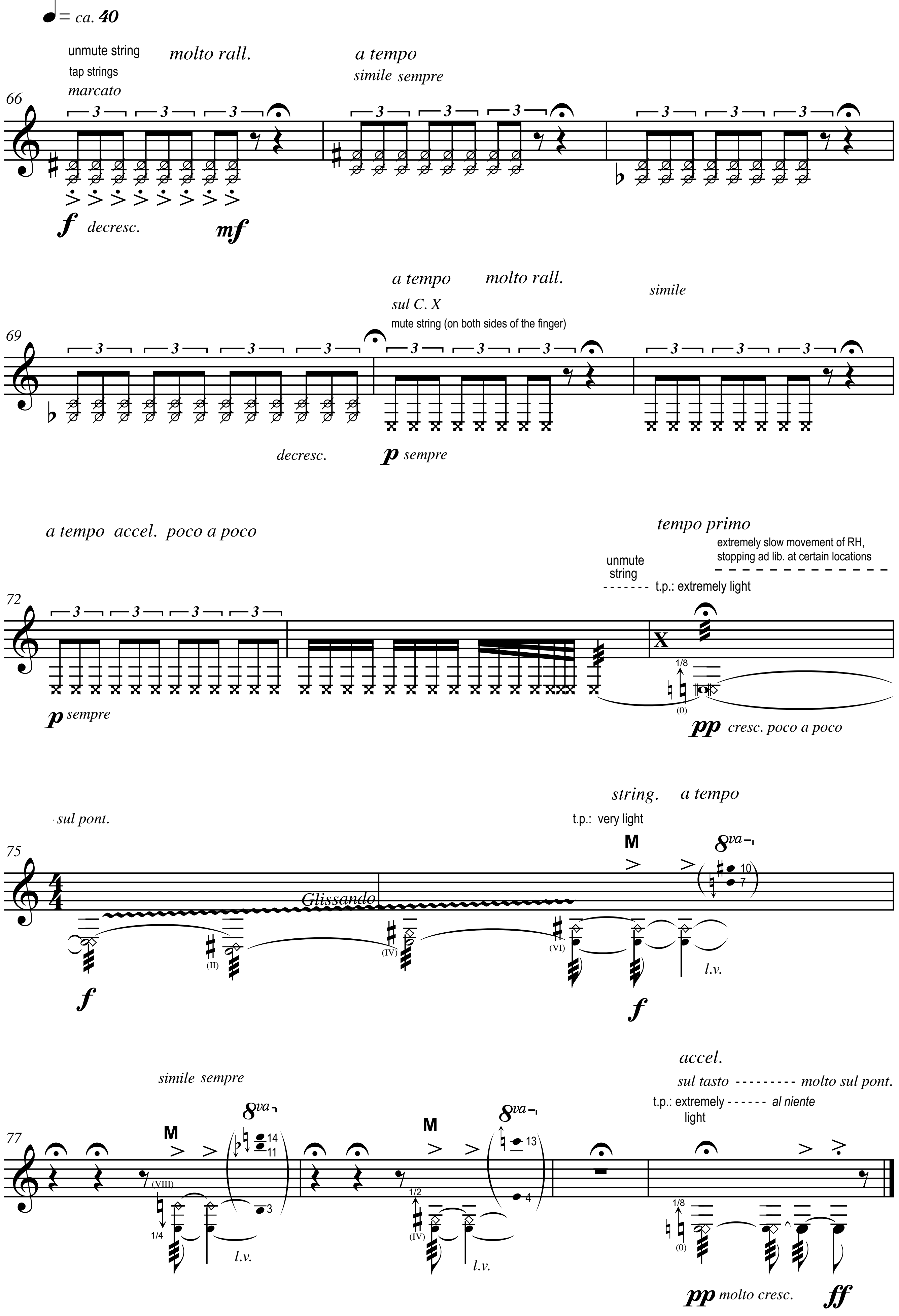
for Jürgen Ruck

Rita Torres
(2015)




touch pressure (t.p.):
dal niente - - - - - - extremely light
- - - - - al niente
M
18
(XII)
cresc.
mp
decresc.
p sempre
t.p.: dal niente - - - - extremely light
- - - - - al niente
dal niente - - - - extremely light
- - - - - al niente
23
(IX)
(VII)
cresc.
mp
decresc.
t.p.: dal niente - - - - - - - - extremely light
- - - - - al niente
27
(V)
p sempre
(pizz.) - - - - - - - - - - - - - - - normale, poco sul pont.
- pizz., ord.
t.p.: dal niente - - - - - - - - - - very light
- - - - - - - - - al niente
8va
32
(VIII)
1/4
p
37
1/2
(IV)


(pizz.) normale, poco sul pont.
t.p.: dal niente very light
pizz., ord.
al niente
M
41
cresc.
mp
decresc.
p sempre
(pizz.) normale, sul pont.
t.p.: dal niente very light
pizz., ord.
al niente
M
47
cresc.
mp poco cresc. decresc.
p
(pizz.) normale, sul pont.
t.p.: dal niente very light
pizz., ord.
al niente
M
52
cresc.
mp poco cresc. decresc.
p
(pizz.) normale, sul pont.
t.p.: dal niente very light
pizz., ord.
al niente
M
56
cresc.
mp poco cresc. decresc.
p sempre
normale
sulla buca
t.p.: extremely light
sul tasto
sul C. X
mute string (on both sides of the finger)
Lunga
61
pizz.
pp sempre


= ca. 40
unmute string
tap strings
marcato
molto rall.
a tempo
simile sempre
66
3
f
decresc.
mf
a tempo
molto rall.
sul C. X
mute string (on both sides of the finger)
simile
69
decresc.
p sempre
a tempo accel. poco a poco
tempo primo
extremely slow movement of RH,
stopping ad lib. at certain locations
unmute
string
t.p.: extremely light
72
p sempre
X
1/8
(0)
pp cresc. poco a poco
string.
a tempo
sul pont.
t.p.: very light
M
8va
10
7
75
Glissando
(II)
(IV)
(VI)
l.v.
f
accel.
simile sempre
sul tasto molto sul pont.
t.p.: extremely
light
al niente
77
14
11
(VIII)
1/4
3
13
1/2
4
pp molto cresc.
ff