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Reaktionszeiten und falsch-positive Antworten von Normalpersonen bei Semiautomatischer Kinetischer Perimetrie (SKP)

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Reaction time and false-positive response characteristics in semi-automated kinetic perimetry in normal subjects

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Abstract

Purpose: To determine the characteristics of reaction time (RT) for semi-automated kinetic perimetry (SKP) in normal subjects.
Design: Clinical trial
Participants: 83 healthy subjects (aged 10 - 79 years, 42 male, 41 female)
Methods: One eye of each individual was examined with SKP using the OCTOPUS 101 perimeter with four different stimuli: Goldmann III4e at 25°/s, III4e at 5°/s, I3e at 5°/s and I2e at 2°/s. For each stimulus combination two centripetally moving RT-test stimuli were presented clearly inside the isopters. Sub-threshold stimuli in the periphery of the visual field served as false-positive catch trials.
Main outcome measure: mean geometric reaction time as a function of stimulus characteristics and age.
Results: Geometric mean of RT over all subjects and stimulus combinations was 453 ms with a coefficient of variation (CV) of 30%. Inter-individual variation of RTs was greater than all systematic variation. RT had a minimum in the third decade (20-29 yrs) and then increased with age. RT with the stimulus III4e at 25°/s were about 20% shorter than RT with the same stimulus moving with 5°/s. False-positive responses had longer response times and a greater variability than correct responses (mean 2,600 ms vs. 453 ms; CV 225% vs. 30%)
Conclusions: Subject-related variability of RT was greater than all systematic variations. Stimulus angular velocity has an impact on RT that may exceed all other systematic influences. The response time to a kinetic stimulus may be used as a discriminator between legal and false-positive responses and can identify stimuli whose starting position is located inside the visual field.
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Introduction

In *static* perimetry, the magnitude of the response window, i.e. the range of the interval between the presentation of the stimulus and the upper limit of response time that is considered to be valid is a critical element in threshold estimation. Responses falling beyond this range may not be assigned correctly to the concurrent stimulus. However, reaction time (RT) in static perimetry can be used to define a response window from which a false-positive response can be derived [1] and from which the timing of the subsequent stimulus is determined. Nevertheless, the utility of the RT-based response window for replacing the traditional false-positive catch trials has been put in question recently [49]. This may be due to inappropriate consideration of the factors influencing RT such as stimulus location, stimulus luminance during the staircase procedure and subject-related factors, such as fatigue and learning.
In *kinetic* perimetry, a systematic displacement of the isopter in the direction of the stimulus movement occurs as consequence of the RTs of the perimetrist *and* the patient. The influence of RT on the outcome of the isopters in manual kinetic perimetry is well-documented but has not been quantified so far [19]. Semi-automated kinetic perimetry (SKP) enables the assessment of RT. For the central isopters RT decreases with increasing stimulus luminance and stimulus size [36] and increases with increasing eccentricity [36].
The extent of the influence of these variables on the peripheral isopters and of stimulus velocity on all isopters is unknown so far. The relationship between RT and incorrect responses to false-positive catch trials is also unknown.

The purpose of this study was firstly to determine the relationship between RT and stimulus velocity, stimulus size and stimulus luminance in normal individuals as a function of age in semi-automated kinetic perimetry (SKP); secondly, to assess the distribution of response times of false-positive answers and thirdly to compare the RT of static and kinetic stimuli.

Subjects and methods

Participants

The cohort comprised 83 normal individuals (42 males and 41 females) aged between 10 and 79 years and stratified such that approximately equal numbers of individuals were enrolled per decade of age. The individuals were drawn from the Tuebingen region and were representative of a broad social and educational background.

Each individual underwent an ophthalmologic and systemic examination and conformed to rigid inclusion criteria. The maximum distance spherical ametropia was ±6.00 diopters sphere and the maximum cylindrical ametropia ±2.00 diopters cylinder. The best corrected distance and near visual acuities in either eye were equal to, or better than, 20/20 and 1.0, respectively, for those aged up to 60 years; better than 16/20 and 0.8 for those aged between 60 and 70 years; and better than, or equal to, 12/20 and 0.6 for those aged over 70 years. All individuals manifested normal ocular motility; no diplopia, strabismus or amblyopia; no nystagmus; normal stereopsis; normal pupil responses; intra-ocular pressures, uncorrected for central corneal thickness, of less than 22 mmHg in either eye; open anterior chamber angles; no clinically significant opacities of the media other than those compatible with age; normal optic nerve head and fundal appearances; no history of congenital colour vision loss; no medication known to affect the visual field; no previous ocular surgery or trauma, including cataract extraction; no history of diabetes mellitus; no history of intra-cerebral disorder; no family history of glaucoma. The arterial hypertension and / or blood pressure were less than 180 mmHg systolic and 90 mmHg diastolic.

Examination procedure

SKP was undertaken with the Octopus 101 perimeter (Haag-Streit Inc., Bern, Switzerland) on one designated eye, determined at random. The background

luminance of the perimeter was 10 cd / m^2. Static perimetry was undertaken with the Octopus 101 perimeter and with the Tuebingen Computer Campimeter (TCC).
All individuals attended for three sessions: at two sessions threshold static perimetry was undertaken; once with the Octopus 101 and once with the TCC. At a third session semi-automated kinetic perimetry was undertaken. The order of the type of perimetry was randomized between individuals. In this paper, we report the results of the assessment of visual reaction times. The data on the reaction – time corrected local kinetic thresholds was published by Vonthein et al. [48].
The static procedures were part of the study published by Hermann et al. [24]. Static threshold perimetry was undertaken using stimulus size III and a background luminance of 10 cd / m^2.

Semi-automated kinetic perimetry was undertaken with four different stimulus combinations.

Table 1: The stimulus characteristics and order of presentation of the stimuli for SKP

Order of Presentation	**Size**	**Luminance**	**Angular velocity [°/s]**	**Starting eccentricity of RT vectors**
First	III	4e	5	40°
Second	III	4e	25	40°
Third	I	3e	5	8°
Fourth	I	2e	2	8°

The various stimuli for SKP were presented centripetally along eight meridians (0°, 45°, 90°, 135°, 180°, 225°, 270°, 315°) designated as “vectors” and defined by the start angle, start eccentricity, stop angle and stop eccentricity. “Normal vectors” were used to determine the local kinetic threshold (LKT). “Reaction time vectors” were used to determine the individual’s reaction time.
At the outset of the examination, one centripetal stimulus (“scout stimulus”) was presented from the periphery to obtain an estimate of the LKT along each of the

eight meridians for each of the four stimuli. The software then calculated, from the estimate of each LKT, the starting position for the presentation of the stimuli during the subsequent session. The software also added two RT vectors with identical stimulus characteristics to each of the four stimulus combinations: one along the horizontal meridian (180° or 0°) and one along the superior-temporal meridian (45° or 135°). The origin of the centripetal RT vectors (table 1) was well within each isopter of each normal individual to ensure that they were perceived immediately and therefore could be used to determine the individual RT. The software also added two Goldmann I1a stimuli per stimulus combination to the vector set which were situated at 88° eccentricity in the temporal visual field to serve as false-positive catch trials.

For the main examination session, each stimulus combination was presented six times to determine the variability of response. Therefore, each session consisted of 248 stimuli (4 stimulus combinations along 8 meridians plus 2 RT vectors, each presented six times, and 2 false-positive catch trials presented only once per combination). The false-positive catch trials, normal and RT stimuli were presented in random order; the sequence of the four different stimulus combinations is shown in table 1. Refractive error was not corrected for the III4e and the I3e stimuli. In addition, no refractive correction was used for the I2e stimulus due to the isopter lying at the border of the trial lens rim and / or lens holder. A rest period of approximately 5 minutes was given after the outset of the examination and a break of at least two minutes after each stimulus combination. The entire session, including the initial scout vectors, lasted 45 to 60 minutes.

To optimize the statistical modelling of the visual field [48], a subset of 9 individuals, three aged between 10 and 19, three between 40 and 49, and three between 70 and 79 years of age, respectively, underwent a second kinetic examination with the OCTOPUS 101 after completion of the study. We used these supplementary examinations to assess the influence of eccentricity on RT with stimuli I4e, II2e and III3e presented at an angular velocity of 3°/s. Two RT vectors started centripetally at 5° eccentricity and two approximately 5° inside the estimated LKT. Stimuli were presented four times along each RT vector. The regular and RT stimuli were presented in random order.

Data analysis

The data sets for the left eyes were converted into right eye format.
The RT for SKP was defined as the time between the onset of the stimulus presentation and the response from the individual and was calculated as:

$$RT = ((eccentricity_{stimulus\ onset} - eccentricity_{stimulus\ perception}) / angular\ velocity) - 0.08\ s$$

A correction term of 0.08 seconds was subtracted from the measure of RT due to a systematic software error resulting from the mismatch between the opening of the stimulus shutter and the start of the recording period for RT. The eccentricities at stimulus onset and stimulus perception were measured to a spatial resolution of 0.1°. Therefore, the maximum precision of the RT depended on stimulus velocity and was 50 ms, 20 ms and 4 ms for stimuli moving at 2°/s, 5°/s and 25°/s, respectively and RT results were rounded to that precision.
The logarithm of RT in perimetry usually follows a normal distribution [10], the mean RTs for each stimulus combination and for each individual were therefore expressed in terms of the geometric mean.
The determinants of RT for SKP were investigated by analysis of variance (ANOVA). The within-subject factors were stimulus combination and stimulus meridian (0° vs. 135°). The between-subject factors were gender, decade of age and dominant eye. The influence of each individual was considered as a random factor nested under the between-subject factors and under the significant two-way interactions and assumed constant coefficients of variation (CV). The degrees of freedom of the denominator (DFden) for the F-test within the ANOVA reflected the number of subjects rather than the number of measurements. The differences between geometric means were reported as percentages with 95% confidence intervals (CI).

To assess the influence of eccentricity in a subset of 9 subjects, the geometric mean for each stimulus combination and starting eccentricity of the RT vectors was calculated.

Static RT was recorded by the examination software with a precision of 100 ms. We calculated the geometric mean over all responded stimulus presentations of the subjects' examinations with the OCTOPUS 101 perimeter.
The relationship between the RT for static perimetry and for SKP was expressed in terms of Spearman's rank-correlation coefficient σ and in terms of the mean difference in RT.

Data analysis was carried out with JMP 4.0.5 statistical software (2001, SAS Inst. Inc., Cary, U.S.A.). The study was approved by the local independent ethics committee and followed the declaration of Helsinki. Written informed consent was given by each individual or by a parent in the case of a minor.

Results

Table 2: Number, gender ratio and mean age of the participants

Age	**No. of Participants**	**Ratio (Male : Female)**	**Mean Age (Standard Deviation; Range), yrs**
10–19	12	5:7	14.1 (2.83; 10.4–18.4)
20–29	12	7:5	24.7 (2.81; 21.3–30.0)
30–39	12	7:5	34.1 (3.29; 30.5–38.7)
40–49	11	7:4	45.3 (3.12; 41.0–49.9)
50–59	12	6:6	54.8 (3.41; 50.2–60.0)
60–69	12	6:6	63.9 (2.62; 60.6–69.5)
70–79	12	5:7	73.7 (2.87; 70.4–80.1)

The randomised designation sequence resulted in 41 dominant eyes and 42 non-dominant eyes with 3751 valid SKP-RT measurements. 16 subjects could not be examined with stimulus I2e as they were unable to see the stimulus. All

RTs below 180 ms and above 1040 ms (except for those serving as false-positive catch trials) were excluded from analysis.

RT in SKP

The distribution of the response times to RT-stimuli in SKP is shown in figure 1. The geometric mean RT for SKP across all subjects and stimulus combinations was 453 ms with a coefficient of variation of 30%. The geometric means for each stimulus combination across each decade of age are given in table 3 and figure 2.

Table 3: The geometric mean and 95% confidence interval [in ms] of RT for SKP for each of the four stimulus combinations at each of the seven decades of age

	10-19 yrs.	**20-29 yrs.**	**30-39 yrs.**	**40-49 yrs.**	**50-59 yrs.**	**60-69 yrs.**	**70-79 yrs.**
I2e, 2°/s	540 (521-560)	459 (443-477)	485 (468-503)	499 (480-518)	619 (590-649)	591 (569-615)	686 (637-738)
I3e, 5°/s	486 (469-503)	411 (396-426)	444 (430-460)	435 (420-452)	482 (466-500)	494 (477-512)	542 (523-562)
III4e, 5°/s	516 (498-535)	411 (397-426)	464 (449-480)	450 (434-467)	471 (454-488)	485 (468-503)	499 (481-517)
III4e,25°/s	397 (383-412)	334 (322-346)	375 (362-388)	375 (362-389)	381 (368-395)	397 (383-411)	390 (376-404)

The ANOVA identified stimulus characteristic, age group and its interaction with stimulus characteristic, subject and interindividual differences in the effects of stimulus characteristics as significant effects on the RT. RT decreased between the first and second decades of age and then increased successively with increasing decade of age ($P<0.0001$). RT depended on the characteristics of the stimulus ($P<0.0001$); it was slowest for the I2e stimulus at 2°/s and fastest for the III4e stimulus at 25°/sec. The increase in RT of older subjects was more pronounced for the smaller stimuli (P<0.0001). The RT was independent of gender (*P* = 0.2004) and dominant eye (*P* = 0.8435). Subjects responded slower to RT stimuli presented along the superior oblique meridian than to presentations along the nasal horizontal meridian (477 ms, CI 466 ms - 488 ms vs. 449 ms, CI 438 ms – 359 ms). The mean difference was only 4 ms for stimuli moving at 25°s and between 25 ms and 50 ms for slower stimuli.

The complete linear model accounted for 52% of the total variation. Thus, the residual variance, i.e. the intra-individual variation in RT, accounts for more of the variance than the systematic variation.

There were significant differences in all pairs of geometric mean RT between various stimulus characteristics (P<0.01, comparison for all pairs with Turkey-Kramer test) with the exception of stimulus conditions III4e at 5°/s and I3e at 5°/s (see figure 3). When comparing RT measured with stimulus III4e moving with 5°/s and 25°/s respectively, we found a significant decrease of RT of 20% (CI 17% to 22%) from slowly to faster moving stimuli (geometric mean 470 ms vs. 378 ms). As subject was a random factor of this model, there was confounding with age. To avoid this problem, a second model with age and its logarithm as co-variables instead of the factors subject and age group was used to assess the influence of age on RT. Age as well as its interaction with the factor stimulus both significantly influenced RT (P<0.001 each). Figure 4 shows a model for predicting RT by age for four stimulus conditions.

We re-analysed the data for the *kinetic thresholds* presented by Vonthein et al. [48] without the correction of subjects' responses for their individual RT. The goodness of the model fit fell from coefficient of determination R^2 = 0.86 to R^2 = 0.83. Figure 5 shows the mean local kinetic thresholds of all subjects and the prediction of the model for stimuli III4e 5°/s and 25°/s in the age group 20-29 years with and without correction for individual RT.

Incorrect responses to false-positive catch trials in SKP

9.8% of the false-positive catch trials yielded incorrect responses (table 4).

Table 4: The percentage of incorrect responses to the false-positive catch trials in SKP by stimulus combination

Stimulus combination	**Responses to false-positive catch trials [%]**
III4e, 25°/s	4.7
III4e, 5°/s	12.5
I3e, 5°/s	8.7
I2e, 2°/s	13.6

The geometric mean response time of incorrect responses to false-positive catch trials was 2600 ms (CV 225%), i.e. the RT was far longer and more variable than the geometric mean of the response time to RT stimuli (453 ms, CV 30%) and of the geometric mean of the responses to stimuli used to measure local kinetic thresholds (1.95 s, CV 82%) [48].

The empirical distribution functions of response times to normal stimuli and to RT stimuli are shown in figure 6. About 10% of the regular stimuli elicited response times shorter than the 95th percentile of the response time to RT test-stimuli. It therefore seems to be possible to distinguish between responses to stimuli that start moving inside or outside the visual field on the basis of the response time with a sufficient precision. Figure 7 shows the empirical distribution functions of response times to regular stimuli and to false-positive catch trials. The separation between regular and false-positive responses is not as good as between normal and RT stimuli, but except for stimulus I2e, the 95%

quantile of the subjects RT is a selection criterion that can identify between 50% and 66% of all false- positive responses.

Influence of eccentricity on RT in SKP

In the subset of nine individuals, the overall geometric mean RT was 499 ms (CV 45%) for stimuli starting at 5° eccentricity and 723 ms (CV 67%) for those starting at approximately 5° inside the local kinetic threshold ($P<0.001$). The increase in RT was greatest for the II2e stimulus (74%), less for the III3e stimulus (34%) and least for the I4e stimulus (15%).

Repeatability

We repeated the SKP-examination in 5 of our 84 subjects with exactly the same set of vectors at least three month after the initial testing. The intra-individual, inter-session differences in RT between the two examinations were between - 25% and + 25% with a median of –5.1% and a CV of 12%.

RT in static perimetry

The overall geometric mean for the RT in static perimetry was 490 ms. The RTs for SKP and for static perimetry are compared in table 5. RTs were generally shorter for kinetic stimuli than for static stimuli. Only to small and dim kinetic stimuli our subjects responded slower than to static stimuli. The correlation was greatest between the static responses and those for stimulus III4e at 5°/s.

Table 5: Correlation and mean difference of RT to kinetic and to static stimuli

Kinetic Stimulus characteristics	***Mean difference of RT [ms] with regard to kinetic and static stimuli***	***95% confidence interval [ms]***	***Spearman's σ***	**95% confidence interval for σ**
III4e, 25°/s	109	97 to 121	0.35	0.15 to 0.53
III4e, 5°/s	16	0 to 31	0.45	0.26 to 0.61
I3e, 5°/s	16	2 to 31	0.41	0.21 to 0.58
I2e, 5°/s	-60	-31 to -88	0.21	-0.03 to 0.43

Discussion

Kinetic perimetry does not only test the local differential luminance sensitivity (DLS), but also the perception of movement, while movement thresholds may differ from those to static stimuli [2,7,34,35]. With conventional kinetic perimetry the recorded location of local thresholds is influenced by the patient's as well as the examiner's RT. The recorded isopters are consequently shifted in the direction of stimulus movement while the extent of this shift depends on the angular velocity of the stimulus. With semi-automated kinetic perimetry it is now possible to correct this shift for the patient's individual RT [48].

It is not possible to use normative values for RT as the intra-individual variance has a bigger influence on RT than all systemic variation. This is not a surprising finding. The list of factors that have been shown to have an impact on visual RTs is impressively long. Gender [45], level of sedation [26], physical activity [46], pathologies of the visual and central nervous system [10,29] oxygen saturation [12] and concentration of sex hormones [44] to name just a few of them. All these items can not be influenced in the setting of the perimetric examination.

Factors influencing RT in kinetic perimetry

In this study we examined the influence of age and stimulus characteristics on RT in kinetic perimetry. It has been known before that RT decreases with increasing stimulus size and increasing stimulus intensity and that RT increases with eccentricity [5,6,22,28,30,31,33,36,39,50,51]. Our results confirm previous findings and show that the correlation between eccentricity and RT in kinetic perimetry is valid also outside the central visual field. We found a RT prolongation of up to 75% measured 5° inwards the LKT compared to the central VF. This finding emphasizes the necessity of placing the RT vectors close to the estimated LKT in order to obtain a more precise estimation of the patient's RT.

The influence of stimulus velocity on RT in kinetic perimetry has not been quantified before. We compared stimulus III4e starting at 40° eccentricity and moving centripetally with 5°/s or 25°/s. RTs were shorter by 20% with faster moving stimuli. Our data suggest that the influence of angular velocity of a moving stimulus may exceed the impact of stimulus size and intensity. There was no significant difference in the geometric means of RT to stimuli III4e 5°/s and I3e 5°/s despite their considerable differences in size and luminance, although we cannot exclude that this is partly due to the fact that the smaller stimuli started at 8° eccentricity, while stimuli III4e started at 40° eccentricity. Another hint to the strong impact of stimulus velocity on RT comes from the comparison of RT to static and kinetic stimuli. Our subjects generally responded faster to kinetic stimuli (table 4). We do admit that the comparison of absolute values is of limited value, as static and kinetic stimuli differed in intensity, location of stimulus presentation and partially in size. However, the mean differences between static stimuli and kinetic stimuli of the same size (Goldmann III) moving at 5°/s are small (16 ms), while the difference in mean RT between static stimuli and kinetic stimuli of the same size moving at 25°/s is 109 ms. The difference in mean RT between kinetic stimuli moving with 5°/s and static stimuli is 16 ms, irrespectively of the size of the kinetic stimulus. Therefore the RT differences between static and kinetic stimuli seem to be influenced by stimulus velocity to a greater extend than by size and intensity. The observed rank correlations indicate that subjects with fast responses in kinetic perimetry are not necessarily characterized by fast responses in static perimetry, too. Absolute values of RT were expectedly shorter in SKP, as kinetic stimuli were presented clearly inside the visual field while the geometric mean of static responses was calculated using stimuli with different intensities, including those close to threshold.

The great influence of stimulus velocity in this study is well in line with former results. Tynan and Sekuler [40] examined the influence of stimulus velocity on visual RT using a computer display and presented up to 500 moving stimuli at the same time within the central VF. They found that RT decreases with target speed. The impact of stimulus velocity on RT in their study was so strong that for stimuli faster than 25°/s stimulus size no longer played a role. It is known that the processing of moving stimuli in the retina and the cortex is different from that of non-moving stimuli. For rabbit retinas Barlow [3,4] has shown that the analysis of motion starts in the retina with ganglion cells responding selectively to direction and speed of moving stimuli. He states that "the discharge [of the ganglion cell] is almost uninfluenced by the intensity of the stimulus spot". Barlow's findings have been confirmed for human retinas by van de Grind et al. [43] who found that high-velocity detectors have shorter delays, irrespectively of their eccentricity, than low velocity-detectors. Zeki and colleagues [2,7,17] have also shown that the perception of a moving stimulus depends on its velocity. With EEG and MEG experiments they found that signals from fast moving stimuli (22°/s) bypass area V1 on their way to area V5. They describe patients with V1 lesions who can detect exclusively stimuli moving faster than 15°/s and patients with lesions in V5 who noticed exclusively stimuli slower than 6°/s.

The increase in RT to stimuli presented along the temporal superior meridian might be explained by the reduced sensitivity in the upper hemifield that has been reported several fold [15,38]. Different explanations have been given to explain this finding [13,24], but neither differences in ganglion cell density or adaptation processes, nor eyelid artefacts give a reason for the fact that the RT difference between stimuli along the two meridians depends on angular velocity. So if the increase in RT along the superior temporal meridian is due to the reduced sensitivity of the upper hemifield, the decrease in sensitivity seems to depend on velocity in case of moving stimuli. However, the mean difference of 30 ms is relatively small and will not produce considerable errors in the correction of kinetic thresholds for the patient's RT.

We found the fastest responses in the age group between 20 and 29 years. From then on, RT increased with age. The increase was more pronounced when small and dim stimuli were used. Teichner [39] reviewed studies that examined the correlation between age, auditory and visual RT and found the same age-dependency. Our study confirms the results of previous studies using kinetic [6,32] and static perimetry [18,50]. RT showed the same dependency on age as visual sensitivity in static perimetry [24]. The explanations given for the depression of visual sensitivity with age in literature are changes of the preretinal structures [14,16] and reductions of the density of photoreceptors in the retina [13] and of neurons in the visual cortex [25,52]. These findings may also explain the increase of visual RT with age.

Hermann [24] and Haas [21] found a decrease in visual sensitivity that was more pronounced in the periphery than in the centre of the 30°- visual field. We do not know if this difference in age-dependency between the periphery and the central visual field is valid also for visual RT in SKP, as our study design did not allow the comparison of RT to identical stimuli presented at different eccentricities within a 30°-VF.

Response times of false-positive responses

Because some time is needed for the transmission of signals from the retina to the brain and further on to the related muscles, visual RTs can not decline below a minimum level even if stimulus intensity is maximized. This minimum value is known to be about 180 ms for RTs with regard to visual tasks [20,41]. Studies report visual RTs to be about 30 - 40 ms longer than auditory and tactile RTs [47]. A significant part of that prolongation is due to the fact that the retina is the only sense organ that performs a complex processing of the signal already at the entrance level before conducting it to the central nervous system. More difficult is the definition of an upper limit of legal response times. A fixed value is usually not the best solution, as very long RT may occur in patients due to cerebral damage [29]. A flexible individual response window could be specified by defining a maximum tolerable within-subject coefficient of variation [1] and eliminating exceeding RTs until variation is below this limit. This was not yet possible with the OCTOPUS software used for this study and we decided to exclude the upper 2.5% of all responses. This percentile resulted in a cut-off value of 1040 ms.

CV of response times to false-positive catch trials was much higher than those of RT stimuli. This is well in line with the findings of Artes [1] who reported similar results with false-positive catch trials in static perimetry. This knowledge about RT in static perimetry has been used to cross-check visual thresholds and to identify false-positive or false-negative responses by defining response windows for reliability indices [1,50] and it is part of the commercially available SITA-algorithm [8]. The use of already available RT information shortens the examination procedure in comparison to algorithms that use special test stimuli to estimate the reliability of patients´ responses. The SITA-Algorithm [23] uses a “listen time” of 180 ms from stimulus onset on and classifies all responses that fall within this time window as false-positive. Wall and colleagues [50] state that this is safe as no legal responses occur faster than 180 ms, but our data suggest that in kinetic perimetry this method fails to detect the majority of false-positive responses as most of them occur not before but within or after the legal response window.

The level of stimulus uncertainty and correct spatial expectancy influence RT [37] and consequently, an auditory or visual warning signal delivered before or even shortly after the presentation of the visual stimulus has been shown to reduce RT [9,27,42]. We did not use an explicit cueing signal in our study, but the sound of the mirror unit that always started before stimulus presentation had the same effect. The distribution of RT to false-positive catch trials shows that our subjects were more likely to press the response button when they heard the sound of the mirror unit that usually comes along with a stimulus presentation for a long time without seeing anything. The highest percentage (13.7%) of false-positive responses was found in the context of stimulus I4e, 2°/s, where small and dim stimuli were used. We conclude that an acoustic cueing that is not followed by a visible stimulus immediately, enhances stimulus uncertainty,

reduces correct spatial expectancy and increases the rate of false-positive responses.
The response time to a kinetic stimulus may give the examiner some valuable information whether the starting point of stimulus presentation is located correctly. Figures 6 and 7 show that it is possible to distinguish between regular stimuli, RT stimuli and false-positive catch trials from the subjects' response times with sufficient precision. If the examination software gave a warning signal whenever the response time to a normal stimulus was faster than the 95% quantile of the patient's RT distribution, the examiner could alter the starting position of the test stimulus to make sure that it originates really in a non-seeing area of the visual field (figure 6). A warning signal in case of responses to a stimulus outside the 95% quantile of the patient's responses to regular stimuli would identify 2/3 (III4e, 25°/s) and about 50% (I3e, 5°/s and III4e, 5°/s) of all false-positive responses (figure 7). However, more research on that topic is needed, as we used only a very small amount of false-positive catch trials (8 per subject) and our results should be generalized with caution.

Conclusion

Visual RT in kinetic perimetry is influenced by a variety of subject-dependent and examination-dependent factors. This and other studies [1,6,11,36,51] showed that inter-individual variability has the most dominant influence on RT. Among the examination related factors, angular velocity has an effect on RT that may exceed the influence of other stimulus characteristics. Measured RT is closer to the "real RT" at the kinetic threshold if the RT vectors are placed about 5° inwards of the expected threshold rather than in the centre of the visual field. The probability of false-positive responses in kinetic perimetry increases with stimulus uncertainty, i.e. in the context of small and dim, slowly moving stimuli. The response time to a kinetic stimulus may be used as a discriminator between legal and false-positive responses and can identify stimuli whose starting position is located inside the visual field.

Figures

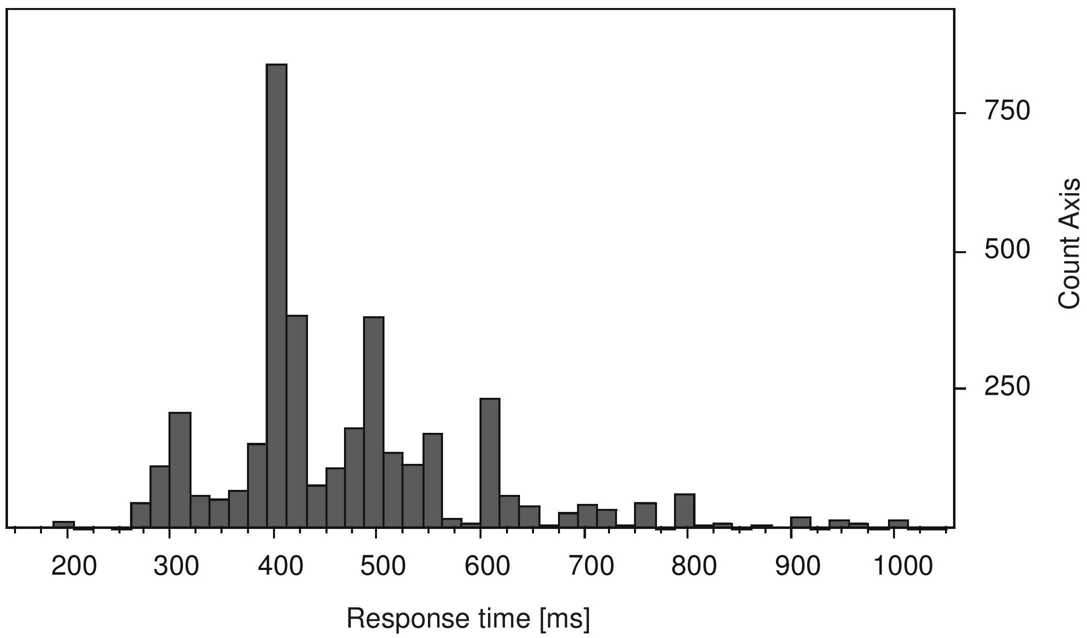

Figure 1: Distribution of subjects' response times to RT stimuli

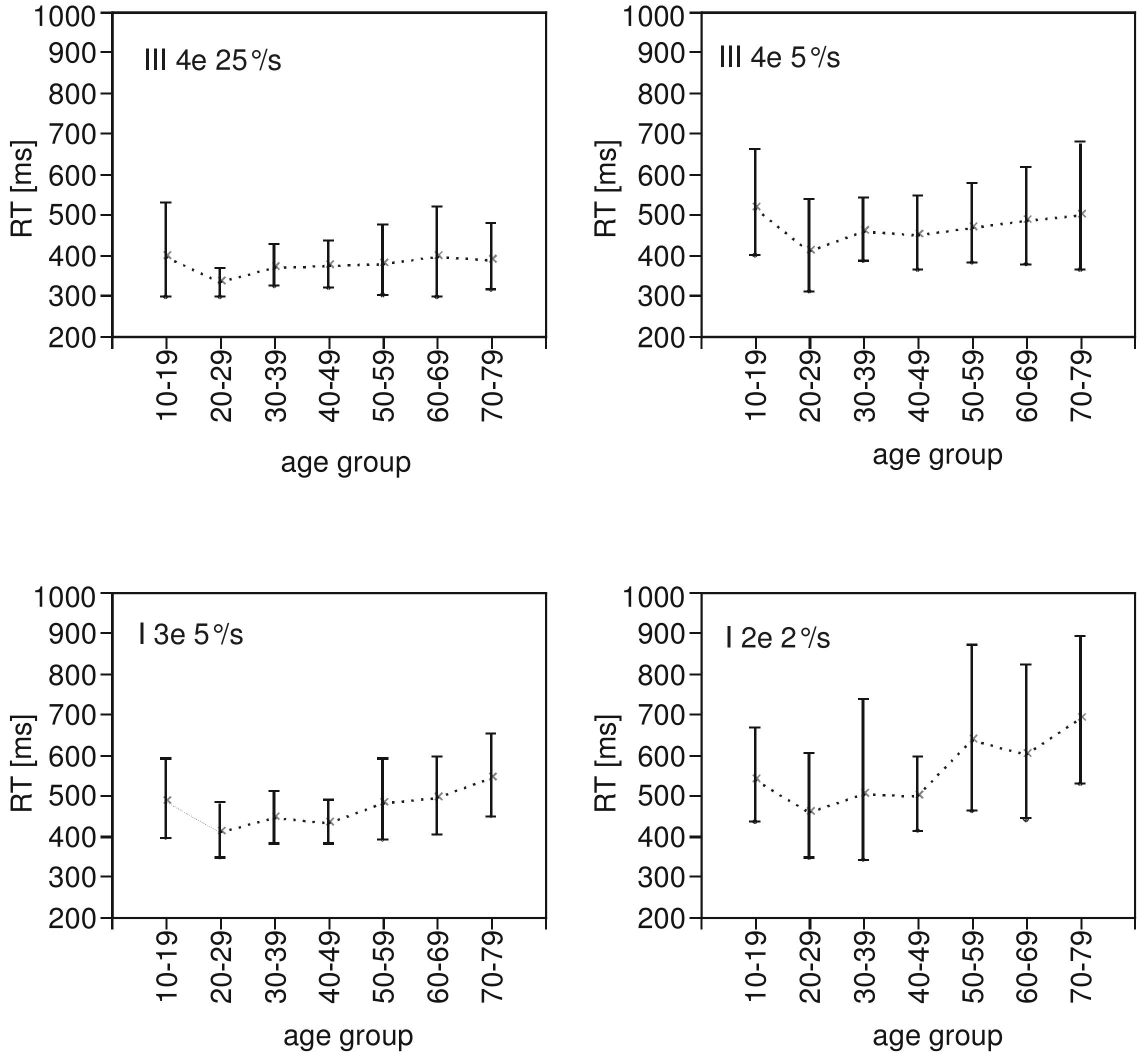

Figure 2: Geometric mean response time and 95% reference intervals by stimulus characteristics and age group

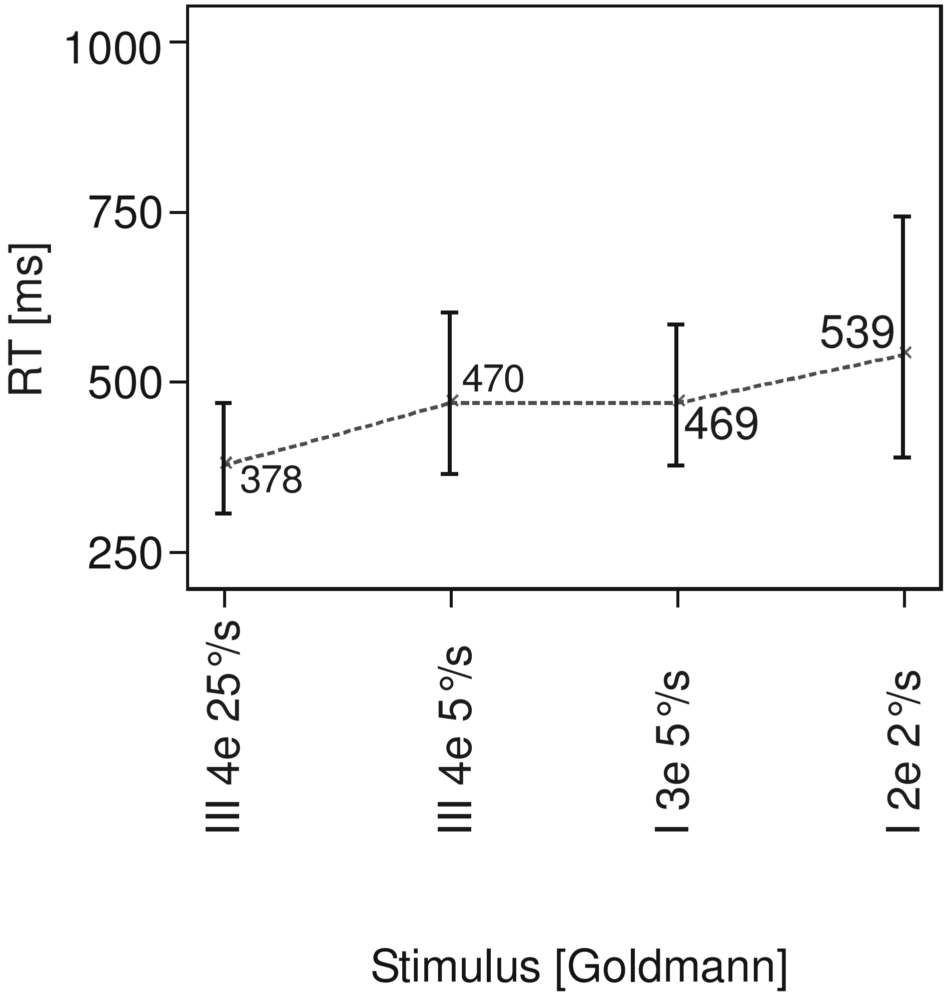

Figure 3: Geometric mean response time and 95% reference intervals by stimulus characteristics averaged over all age groups

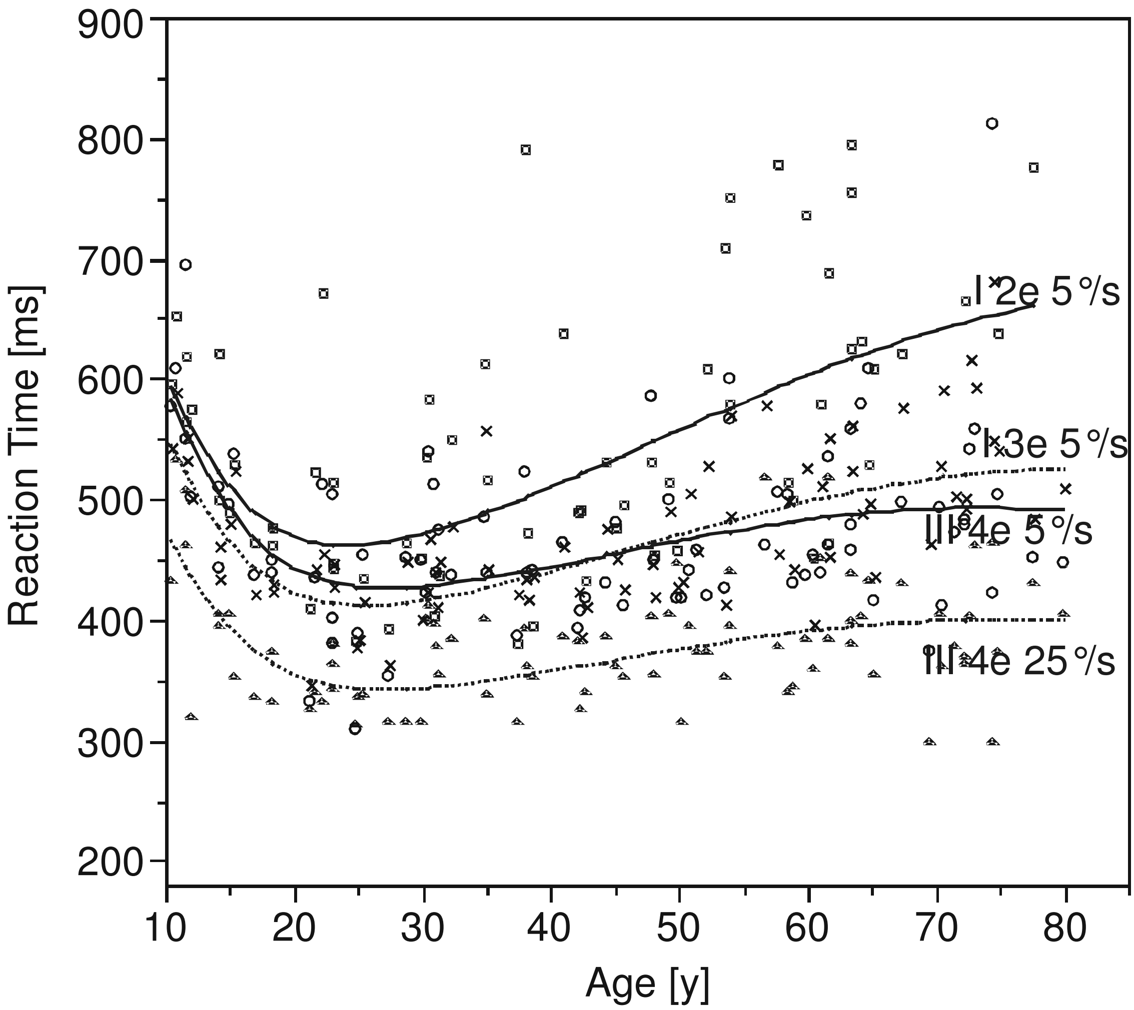

Figure 4: Model prediction of geometric mean RT by age, stimulus characteristics (△ III 4e 25°/s, ○ III 4e 5°/s, × I 3e 5°/s, □ I 2e 2°/s) and individual (symbols)

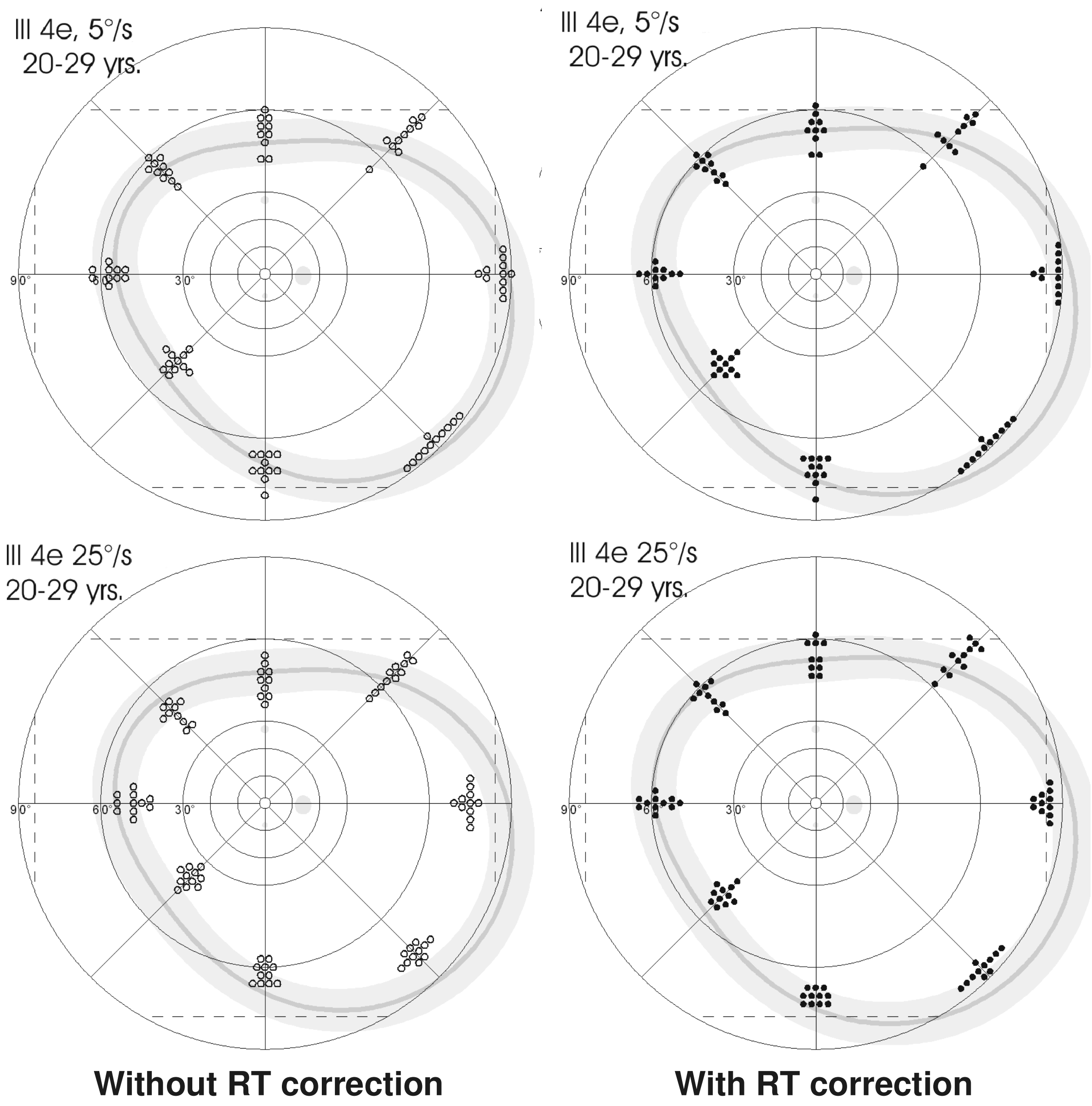

Figure 5: Mean local kinetic threshold of 11 subjects superimposed on the reference band (shaded) with and without RT correction

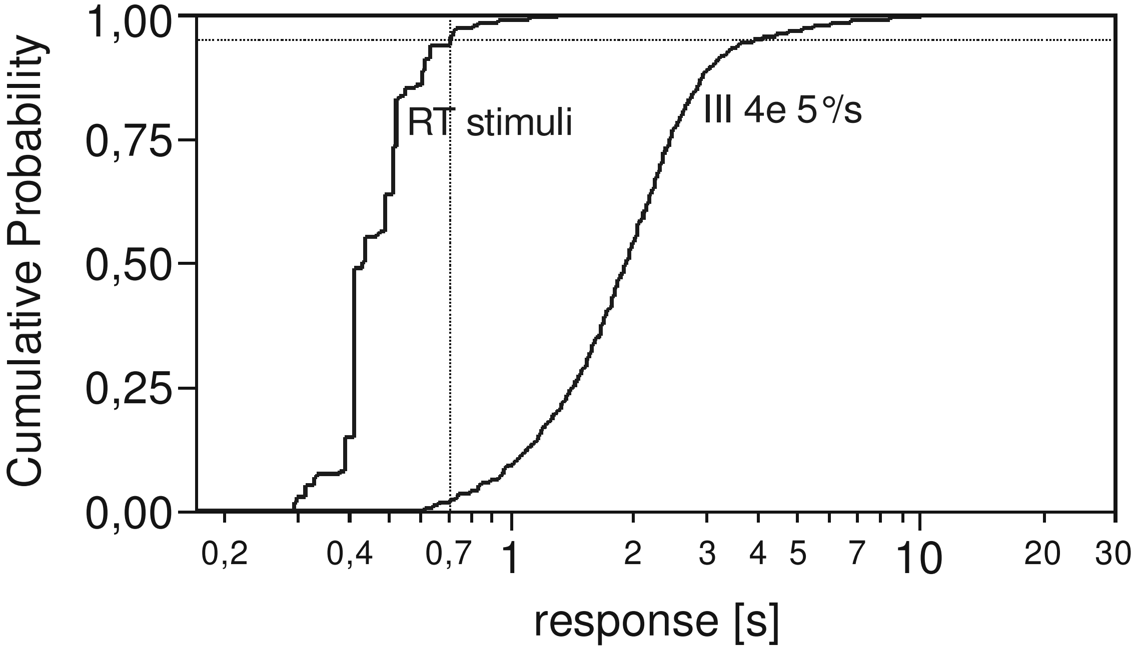

Figure 6: Empirical distribution functions of response times to stimuli seen at once ("RT") and moving from not seeing to seeing visual field ("normal") for stimulus III4e at 5°/s. About 10% of the normal stimuli elicited response quicker than the 95th percentile of RT (vertical line).

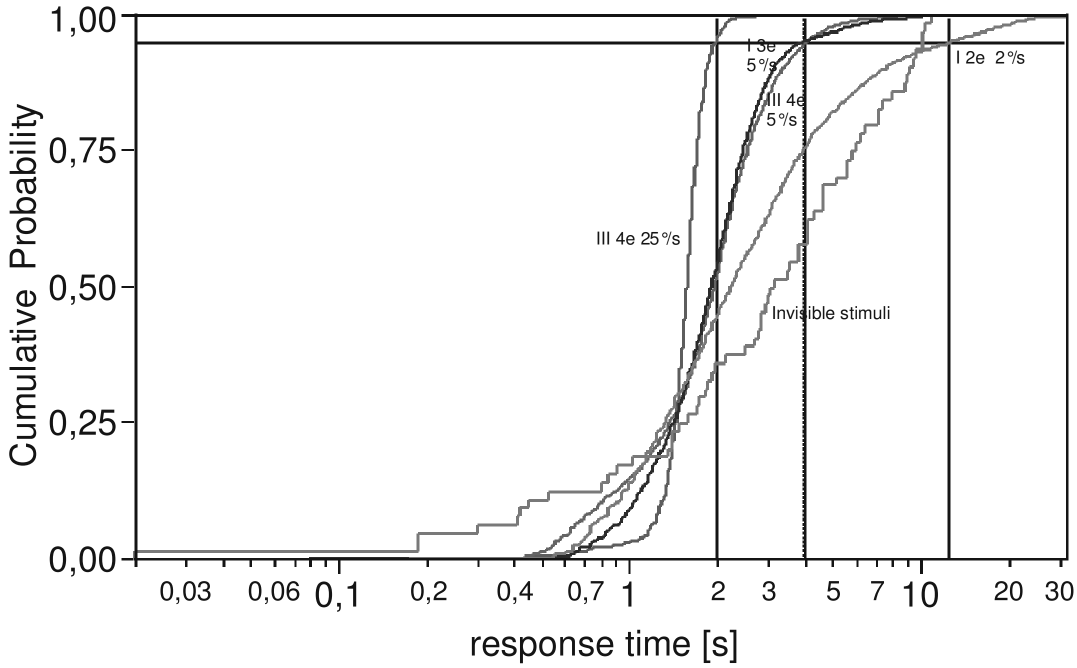

Figure 7: Empirical distribution functions of time to response for invisible stimuli (shallow steps) and normal stimuli (ever steeper curves). Vertical lines indicate, how labeling the upper 5% of response times false-positive (FP) would correctly label 2/3, 1/2 or no true false-positive responses.

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