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RESEARCH NOTE

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CRT screens may give rise to biased estimates of interhemispheric transmission time in the Poffenberger paradigm

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Abstract It has been shown that computer video-display units do not emit luminance uniformly over the entire screen, but emit more light on the right hand side than on the left hand side. The present study investigates whether this luminance asymmetry has implications for the manual and vocal estimates of interhemispheric transmission time (IHTT) in the Poffenberger paradigm. In particular, it is shown that previous reports of right visual-field advantages for vocal responses are an artifact of the luminance asymmetry of computer screens and that this asymmetry also has implications for estimates of differences in transmission time from the right to the left hemisphere in manual responses. In addition, we examined the impact of stimulus intensity and dark adaptation to the IHTT estimates and found that neither had an effect. This is in line with previous evidence that interhemispheric transfer in the Poffenberger paradigm does not depend on the transfer of visual information.

Keywords Interhemispheric transmission time · Poffenberger paradigm · Corpus callosum · Laterality · CRT screens

Introduction

In the Poffenberger paradigm, a simple behavioral technique is employed to estimate the time needed to transfer information from one cerebral hemisphere to the other. In this task, participants press on a key with the left or right hand as soon as a light flash appears to the left or right of fixation. Over a series of 16 studies (Marzi et al. 1991), it has been observed that responses are consistently faster when participants react with the right hand to stimuli presented to the right of fixation, and with the left hand to stimuli presented to the left of fixation (the uncrossed condition). In the crossed condition, participants react with the right hand to stimuli on the left or with the left hand to stimuli on the right. The difference between crossed and uncrossed responses (CUD) is interpreted as interhemispheric transmission time (IHTT) (see Marzi et al. 1991 for an overview).

Another method that has been proposed to estimate IHTT is based on vocal reactions (see Brysbaert 1994 for a review). In this paradigm, participants have to say a word as soon as the light is flashed in one or the other visual hemifield (VHF). The difference between reaction times (RTs) to stimuli in the left visual field (LVF) and RTs to stimuli in the right visual field (RVF) may yield another estimate of IHTT in right-handers. Contrary to the unimanual estimates of IHTT, the verbal estimates have been rather inconsistent. Four studies reported a reliable RVF advantage, but three studies did not (see Table 1).

The present study

The present study started from the observation that the right side of a computer screen is slightly brighter than the left side (e.g., Ratinckx et al. 1997). This was true for all CRT screens we tested and probably reflects a characteristic of the phosphor beam. Given that a considerable number of studies has been run with a computer screen, this may have considerable implications on the IHTT estimates due to the lateralized presentation of stimuli.

To look directly at the effects of the luminance distribution over a CRT screen, we ran two simple reaction-time tasks (one with manual reactions and one with vocal reactions), in which we turned the CRT screen upside down for half of the participants. In addition, we examined the effects of stimulus intensity and dark adaptation on IHTT estimates. This was done to find out whether these variables would interact with the luminance distribution of the CRT screen.

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Table 1 Simple reaction time (SRT) studies of interhemispheric transmission time (*IHTT*) based on vocal reactions to lateralized light flashes. *RT* Reaction time, *LVF* left visual field, *RVF* right visual field

Source	n_{subj}	$n_{\text{obs/subj}}$	RT_{LVF}	RT_{RVF}	IHTT (ms)
Brysbaert (1994)					3.4*
Geffen et al. (1971)					–0.7
Lines and Milner (1983)[a]					6.9*
Milner and Lines (1982)[b]					8.3*
Sergent and Meyers (1985)					–4.6
St. John et al. (1987)					7.4*
Tassinari et al. (1983)					0.3

[a] Only participants showing an overall right VHF advantage were used in this study. This resulted in an exclusion of four of the 24 participants

[b] Only participants showing an overall right VHF advantage were used. Twelve of the 24 participants were excluded

*$P<0.05$

Materials and methods

Participants

Forty-eight undergraduates of Ghent University participated for course credit. All participants (age range: 17–35 years) were male and right-handed, as confirmed by a Dutch translation of the Oldfield (1971) questionnaire. Participants were unaware of the purpose of the experiment and had normal or corrected-to-normal vision. The data of two additional participants were excluded from the analysis due to many anticipatory reactions.

Procedure

Stimuli were presented on a Pentium PC connected to a 15″ Yakumo color monitor. Measurement of the luminance of the screen with a photometer (Minolta LS-110) was done under the same circumstances as in the experimental situation (i.e., the photometer was pointed to the area of stimulus presentation in a completely dark room at a distance of 60 cm between screen and photometer). This revealed that the right side (mean =37.9 cd/m^2) of the screen was slightly brighter than the left side (mean =36.8 cd/m^2), as has been the case for all CRT screens we've tested. The difference persisted when the screen was turned upside-down (37.9 cd/m^2 for the left side and 36.8 cd/m^2 for the right side). Unimanual responses were measured with an external button box, vocal responses were measured with a voice-key. Stimulus presentation and response timing were measured to the nearest millisecond.

The stimuli were light flashes presented 75 mm to the left or the right of a fixation mark consisting of two short vertical lines of 3 pixels separated by a gap of 9 pixels. The participants were asked to fixate the gap. They sat at a distance of about 60 cm from the screen (there were no head restraints). Stimulus intensity was manipulated by varying the number of pixels of the light flash: the faintest stimulus consisted of a single pixel, followed respectively by rectangular light flashes of 2x2, 4x4, and 8x8 pixels. To ensure that participants would remain dark adapted, each stimulus intensity was randomly presented at three possible areas on the screen: one at the level of the fixation gap, and one 1 cm above or 1 cm below the level of the fixation location. The experiment was run in complete darkness.

A trial started with a foreperiod of 1000 ms in which no stimulus was visible, followed by the presentation of the fixation mark. After a second random foreperiod of 450, 500, 550, or 600 ms, the light flash was presented for 28 ms randomly to the left or to the right of the fixation location. In the manual condition, the participant's task was to press the response button as fast as possible. The response button was placed on the midline, and the participant had to react unimanually with the index finger. The hand with which the participant reacted was counterbalanced in an ABBA form; the hand with which he started was also counterbalanced. In the verbal condition, the participants had to say "ja" (the Dutch word for "yes") as soon as they saw the light flash.

In the first part of the experiment, eight experimental blocks of 96 trials were run, in which half of the participants responded manually while the other half made a vocal response. After about 35 min, when participants were completely dark adapted, the second part started. In this session, four experimental blocks of 96 trials were run, in which response modality was reversed, i.e., the first half of the participants made a vocal response and the second half a unimanual response. At the end of each block of 96 trials, the participants received feedback about their RTs. In the beginning of each part of the experiment, the participants received 24 practice trials to explain the nature of the task. For half of the participants, the screen was turned upside-down.

Results

Only average RTs in the range of 100–1000 ms were analyzed. For the manual responses, the percentage of outliers, averaged across participants, amounted to 4.7%: 3.7% due to anticipatory RTs, 1% due to too slow RTs or omission errors. For the vocal responses, the percentage of outliers amounted to 2.9%: 2.5% due to anticipatory RTs, 0.4% due to too slow RTs or omission errors.

Analysis I

This analysis was done to determine whether screen orientation would influence the IHTT (e.g., the CUD scores in the manual condition and the LVF-RVF difference in the vocal condition). All data of the 48 participants were used for this analysis (the averaged means of half of the participants were based on eight experimental blocks, four experimental blocks were used for the other half of the participants).

Manual task

A 2x2x4x2 ANOVA was run with the within-subjects factors hand, VHF, and stimulus intensity (four levels) and the between-subjects factor screen orientation (normal vs. upside-down).

Only the main effect of stimulus intensity was significant [$F(3,138)=178.6$, $P<0.0001$]: reaction times were faster with increasing stimulus intensities (253.1 ms;

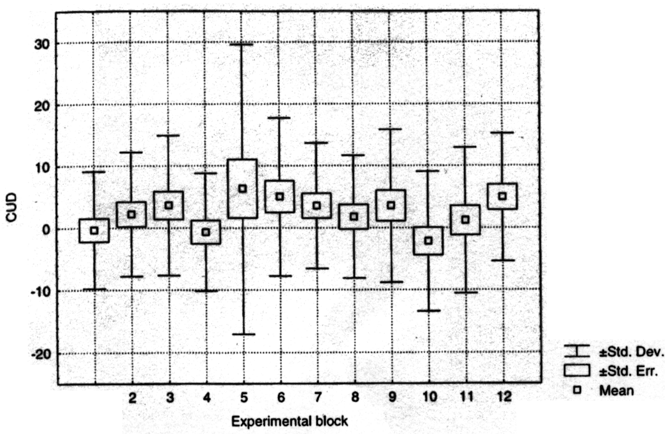

Fig. 1 *CUD* scores (the difference between crossed and uncrossed responses) for each experimental block in the manual-response condition. The first eight blocks (session 1) are based on one half of the participants, the last four on the other half (session 2)

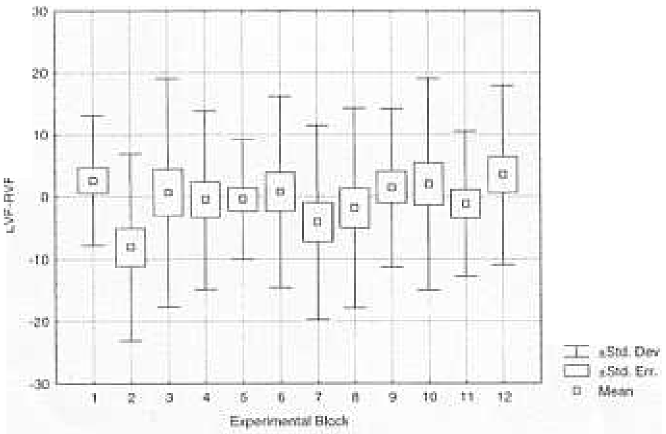

Fig. 2 The difference in reaction times between responses to stimuli in the left visual field and right visual field (*LVF–RVF* scores) for each experimental block in the vocal-response condition. The first eight blocks (session 1) are based on one half of the participants, the last four on the other half (session 2)

242.3 ms; 235.0 ms; 229.0 ms). VHF was marginally significant [$F(1,46)=3.5$, $P<0.07$] with faster RTs to the LVF (239.0 ms) than to the RVF (241.0 ms).

The interaction between hand and VHF was significant [$F(1,46)=9.7$, $P<0.005$] reflecting the IHTT. The CUD equaled to 0.7 ms for the right hand (239.0 ms vs. 238.3 ms) and to 3.8 ms for the left hand (239.2 ms vs. 243.0 ms) (the stability of the CUD scores over experimental blocks is shown in Fig. 1).

The two-way interaction between screen orientation and VHF was also significant [$F(1,46)=4.9$, $P<0.05$]. The upright orientation revealed a small RVF advantage (233.6 ms vs. 233.3 ms), whereas a LVF advantage (244.1 ms vs. 248.0 ms) emerged with an upside-down screen. No other main or interaction effects were significant ($F<2.7$).

Vocal task

A 2×4×2 ANOVA was performed with the following within-subjects factors: VHF and stimulus intensity (four levels). The between-subjects factor screen orientation was also included.

Stimulus intensity was significant [$F(3,138)=116.0$, $P<0.0001$]: participants responded faster with increasing stimulus intensity (308.9 ms; 298.8 ms; 294.1 ms; 288.0 ms). The main effect of screen orientation [$F(1,46)=8.3$, $P<0.007$] was also significant, indicating faster reactions (285.0 ms) in the upright condition than in the upside-down condition (310.0 ms). This might be due to the unusual position of the screen in the upside-down condition. VHF was not significant ($F<0.02$) (LVF=297.3 ms; RVF=297.5 ms; for the stability of the LVF–RVF scores over experimental blocks, see Fig. 2), but interacted with screen orientation [$F(1,46)=3.9$, $P<0.055$]. There was a RVF advantage (285.9 ms vs. 283.8 ms) in the upright condition and a LVF advantage in the upside-down condition (308.8 ms vs. 311.1 ms). No other main or interaction effects reached significance ($F<1$).

Analysis II

We also investigated the influence of dark adaptation on IHTT. In a first analysis, we compared the first four experimental blocks of the experiment, in which participants were not yet dark adapted, with the four last experimental blocks, in which participants were completely dark adapted. In a second analysis, we compared the first four blocks with the last four blocks of the first experimental session. Both analyses yielded the same results. Dark adaptation did not modulate IHTT (see Figs. 1 and 2), nor did it interact with any other variable of the design.

Discussion

Two research questions were addressed here. First, we examined the effect of the luminance asymmetry of CRT screens on both manual and verbal estimates of IHTT. Second, we examined the relative contribution of stimulus intensity and dark adaptation to IHTT estimates.

For the manual responses, there was a significant interaction between hand and VHF. This interaction reflects the interhemispheric transfer and is similar to the hand × VHF interaction obtained in the meta-analysis of Marzi et al. (1991). Interestingly, the upright screen orientation gave rise to a small RVF advantage, whereas an upside-down screen resulted in a reliable LVF advantage. This means that the LVF advantage usually found in IHTT studies (Marzi et al. 1991) will be obscured when a CRT screen is used without an appropriate control for the asymmetry in luminance distribution (see, e.g., Brysbaert 1994; Jeeves and Moes 1996). The underestimation of RTs to stimuli in RVF also inflates the CUD for the right hand (estimated by means of the LVF–RVF difference) and underestimates the CUD for the left hand (estimated by means of the RVF–LVF difference).

The luminance asymmetry of CRT screens also has implications for vocal estimates of IHTT. Previous research had suggested that a significant LVF–RVF difference can be obtained if enough participants are tested and enough observations are made per participant (see Table 1). However, it turns out that all studies that met this requirement also worked with CRT screens. The present study strongly suggests that this confound is the true origin of the LVF–RVF difference: with an upright screen position, we obtained the "expected" difference of 2.1 ms, but with the screen upside-down, the effect turned into a difference of –2.3 ms. As in the present study, all other studies that did not make use of CRT screens (Geffen et al. 1971; Sergent and Meyers 1985; Tassinari et al. 1983) failed to obtain a significant RVF advantage.

Finally, dark adaptation did not modulate IHTTs. IHTT did not change as a function of stimulus intensity either. This is in line with previous evidence (e.g. Brysbaert 1994) that interhemispheric transfer in the Poffenberger paradigm does not consist of visual information.

In conclusion, our study shows that only manual responses yield valid estimates of IHTT, as indicated by a reliable VHF by hand interaction. In contrast, the significant RVF advantage for vocal responses was not replicated when the luminance of the stimuli in LVF and RVF was controlled for. This indicates that simple verbal RTs are unsuitable for measuring IHTT. Neither dark adaptation nor stimulus intensity affected IHTT, supporting previous evidence that interhemispheric transfer depends on visually insensitive pathways.

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