VISUAL COGNITION, 2003, *10* (5), 537–547

Do ‘‘Chinese and American see opposite apparent motions in a Chinese character’’? Tse and Cavanagh (2000) replicated and revised

Jing-Ling Li and Su-Ling Yeh

Department of Psychology, National Taiwan University, Taipei, Taiwan

In a paper entitled ‘‘Chinese and Americans see opposite apparent motions in a Chinese character’’, Tse and Cavanagh (2000) showed that when a Chinese character was presented stroke by stroke and the participants were asked to judge the motion direction of the last stroke (a horizontal line), the American participants perceived the direction predicted by transformational apparent motion, while the Chinese participants saw the opposite, writing direction. We demonstrate that Chinese readers do not always perceive the direction of writing; only when there are writing clues (such as a handwritten script presented in a writing sequence for a long enough duration) is the writing direction perceived. The top-down factors that make Chinese readers see the writing direction are the script and the stroke sequence, which are derived from writing experiences.

Tse and Cavanagh (2000) reported that ‘‘Chinese and Americans see opposite apparent motions in a Chinese character’’ for the last stroke of the Chinese character ‘‘当’’, when the script was similar to handwritten characters (i.e., in chirographic script, as shown in Figure 1a) presented stroke-by-stroke for 450 ms per stroke in a writing sequence. Although the entire stroke appeared all at once, the participants had to report the perceived drawing-out direction of the last stroke, the bottom horizontal line. According to transformational apparent motion (Tse, Cavanagh, & Nakayama, 1998), participants tend to group stimuli and see the transformation of the shape of an object by combining stimuli in sequential frames. Since the right-hand end of the last stroke of the character ‘‘当’’ is connected to the already present vertical stroke, the perceived direction of the last stroke should be from right to left. Consistent with this hypothesis, 10

Please address all correspondence to: Su-Ling Yeh, Dept of Psychology, National Taiwan University, No. 1, Sec. 4, Roosevelt Rd., Taipei, Taiwan, 106. Email: suling@ccms.ntu.edu.tw

This research was supported by National Science Council in Taiwan (NSC 89-2413-H-002-002). We thank Daisy L. Hung, Timothy L. Hubbard, and an anonymous reviewer for their comments on earlier versions of this manuscript, and Yi-Chen Chen for collecting pilot data.

http://www.tandf.co.uk/journals/pp/13506285.html DOI:10.1080/13506280244000195

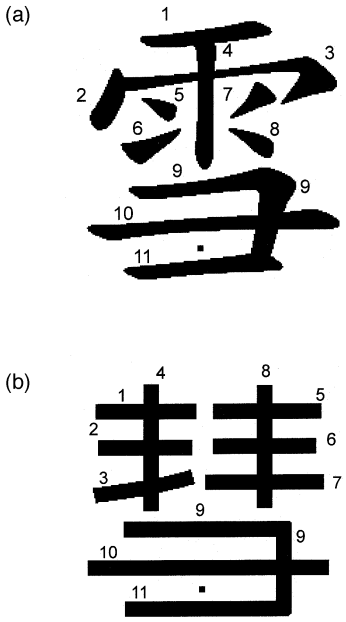

Figure 1. The Chinese characters (a) ''雪'' and (b) ''彗'' along with a fixation dot and stroke labels. The script of ''雪'' is chirographic, and the script of ''彗'' is square. Note that the stroke labels were not shown in the experimental presentation.

out of 10 American participants saw the stroke being drawn out from right to left. However, 7 out of 10 Chinese participants saw the opposite direction, from left to right, in accordance with the conventional writing direction they had learned previously. Tse and Cavanagh (2000) concluded that: ''There is therefore a learned component to motion perception arising from top-down expectations capable of overriding bottom-up cues to motion'' (p. B27).

In this study, however, we demonstrate that native readers of Chinese also perceive the right-to-left direction, just as Tse and Cavanagh's American participants do; the particular situation in which Chinese participants perceive the opposite direction is in the condition used by Tse and Cavanagh (2000). The Chinese readers' perception of the direction is due to writing clues, embedded in the stimulus display, and these clues are perceived by the Chinese, but not by the American participants. We suppose that the factors related to writing clues in the display of Tse and Cavanagh (2000) are stroke sequence and character script, as explained below, and such information can be extracted well only when the exposure duration of the strokes is long enough.

While learning to write Chinese characters, it is customary to reproduce characters many times according to a conventional, standard writing sequence.

A typical Chinese character is usually written in the sequence of top-left, bottom-left, top-right, and bottom-right for the four quadrants, while writing outer strokes before inner ones, and larger strokes before smaller ones. The writing sequence can be considered as a graphomotoric code that helps to remember complex stroke patterns (Klima, Tzeng, Fok, Bellugi, Corina, & Bettger, 1999; Tzeng, Hung, Chen, Wu, & His, 1986). When strokes are presented in a writing sequence, the participants recognize the character more quickly than when the strokes are presented in a random sequence (Flores d'Arcais, 1994). Thus, it is possible that the writing sequence in Tse and Cavanagh (2000) is crucial in obtaining an effect on perceived motion in the last stroke. This leads us to the first experimental manipulation of this study: The presentation sequence of each stroke. We predict that randomizing the stroke sequence should eliminate the effect of writing direction, and that, in this case, reports of direction of motion from Chinese participants should be the same as those from American ones.

In addition to the writing sequence, character script may be another factor critical to the perceived direction of motion. Handwritten or chirographic script contains information about the direction of writing; the starting position of each stroke should be heavier, and thus larger, than the other parts of the same stroke. When presenting handwritten symbols, the writing trace revealed by the script can activate a dynamic mental representation and influence judgement of the direction of motion (Freyd, 1987, 1993). It has been shown that the direction of drawing out of a symbol in a training period affected static pattern recognition in a test period (Freyd, 1983a, 1983b). When handwritten symbols were presented statically, the writing direction could nevertheless be inferred from the script (Babcock & Freyd, 1988). Hence, it is possible that the Chinese participants are given clues by the chirographic script used by Tse and Cavanagh (2000), and may therefore expect a left-to-right production of the last stroke. Even though the script information may also be used by American participants (Babcock & Freyd, 1988), it could be a stronger cue for Chinese participants, given their lifelong exposure to it. Since the trace of the direction of writing is more obvious in the chirographic script (as shown in Figure 1a) than in other scripts, such as the square script (Figure 1b), we manipulated these two forms of scripts in this study to see whether indeed only the chirographic script, and not the square script, would induce the left-to-right direction of motion.

The perception of the direction of the last stroke of the Chinese character presented by Tse and Cavanagh (2000) may be influenced by stroke sequence and character script, but it could also be influenced by factors that are important to apparent motion. One factor, that may be particularly important in this case, is the exposure duration of a stimulus (Anstis, 1980; Braddick, 1980). In a Ternus apparent motion display, for example, a completely different kind of motion is perceived at short durations than at long durations (Petersik & Pantle, 1979; Ternus, 1926). Similar results came from a study on biological motion (Shiffrar & Freyd, 1993), which showed that a long, possible path of biological motion

was perceived at long durations, and a short, impossible path at short durations. In Tse and Cavanagh (2000), each stroke was presented for 450 ms, which is a relatively long duration that may have allowed top-down factors to affect the perceived direction of motion. Hence, the hypothesis arises that at a shorter time course, that could hamper the development of top-down effects, Chinese participants are likely to perceive the same direction of motion as American participants do. That is, with the same stimulus arrangements, the stroke duration may determine whether Chinese and American viewers perceive the same or the opposite direction of motion.

EXPERIMENT 1

Three factors were manipulated. Two were assumed to be top-down—character script and stroke sequence—and a third was assumed to modulate the effects of the first two—exposure duration. We predict that, in conditions lacking top-down clues or when stimuli are presented at short durations, bottom-up effects on apparent motion direction should also be obtained for Chinese readers. In this study, participants (all native Chinese readers) were asked to judge the direction of motion of the last horizontal stroke of the Chinese characters, ''雪'' and ''彗''. These two characters were chosen because our participants were all Taiwanese and more accustomed to traditional, more complicated, characters. The two characters have similar high frequencies of occurrence, matching stroke counts, and both have a configuration similar to the simplified character ''当'' used by Tse and Cavanagh (2000).

Method

Thirty-two undergraduates of National Taiwan University participated in this experiment. They were native Chinese readers with more than 10 years writing experience and were naïve about the purpose of this study.

All the stimuli were presented on an EIZO 17″ colour monitor with a 60 Hz refresh rate and a 640 × 480 pixel resolution. The participants sat in front of the monitor at a distance of about 60 cm. The stimuli were white on a black screen. The character had a size of 8.5° × 8.5° in chirographic script, and 8° × 8.5° in square script. The chirographic script, as used in Tse and Cavanagh (2000), was similar to the handwritten pattern produced with a Chinese writing brush. The square script was created by combining rectangles. The fixation point was a 0.3° × 0.3° square, located in between the bottom two horizontal strokes in the centre above the last stroke (Figure 1), and was presented throughout the trial.

For writing sequence conditions, the conventional writing sequence was used, being 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, and 11 for both ''雪'' and ''彗'', with the number indicating the stroke order in Figure 1. For random sequence conditions, each stroke was presented in the order of 7, 2, 6, 1, 10, 4, 3, 8, 9, 5, and 11 for ''雪'', and 8, 3, 10, 1, 6, 5, 4, 2, 9, 7, and 11 for ''彗''. The critical strokes,

strokes 9 and 11, were always presented at the 9th and 11th positions, the same as in the writing sequence conditions.

The experiment was a 2 × 2 × 2 factorial design. The three factors were script (chirographic vs. square script), stroke sequence (writing vs. random), and stroke duration (45 ms vs. 450 ms). The eight conditions were all within-subjects. Each participant performed each of the eight conditions in one trial, with half of the trials containing the character ''雪'' and the other half ''彗''. The eight trials were completely randomized for each participant. The two characters appeared in a yoked design in such a way that half of the participants saw ''雪'' in one trial while the other half saw ''彗'' in the same trial, and each participant saw four ''雪''-trials and four ''彗''-trials.

Prior to the beginning of each trial, the entire character was visible all at once, along with a fixation point, after which the character disappeared and then reappeared stroke by stroke without an interstimulus interval between the strokes. The participant was asked to maintain fixation and, after the completion of the presentation, to choose how the last stroke appeared to be drawn out: Left-to-right, right-to-left, or all-at-once (a forced choice). No practice trials preceded the formal ones, but the trials were presented only after the participants had understood what to report. They were allowed to see the presentation again if they had been unsure.

Results and Discussion

The results for the two characters, ''雪'' and ''彗'', were not significantly different, $\chi^2(14) = 20.5$, $p = .11$, and the data from the trials with these two characters were collapsed. For further analysis, results of the reports were dummy coded as follows: The right-to-left direction was coded as −1, no motion as 0, and left-to-right as 1. Thus, higher summed values indicate a stronger tendency to perceive a left-to-right writing direction. These values were then submitted to a three-way analysis of variance (ANOVA) with the factors ''script'', ''sequence'', and ''duration''.

As shown in Table 1, the main effects were all significant. The tendency to report the right-to-left direction was stronger in the square script (−0.52) than in

TABLE 1
Mean of the dummy code values in each condition of Experiment 1

	Chirographic script		*Square script*	
Duration	*Normal sequence*	*Random sequence*	*Normal sequence*	*Random sequence*
45 ms	−0.59	−0.88	−0.81	−0.88
450 ms	0.34	−0.19	−0.03	−0.38

the chirographic script condition (−0.33), $F(1, 31) = 6.48$, $MSE = 1.59$, $p < .05$; and stronger in the random sequence (−0.58) than in the writing sequence condition (−0.27), $F(1, 31) = 19.02$, $MSE = 0.38$, $p < .0001$; and also stronger in the 45 ms duration (−0.79) than in the 450 ms conditions (−0.06), $F(1, 31) = 62.19$, $MSE = 0.27$, $p < .0001$. No two-way or three-way interactions were found.

Note that, the only positive value (0.34) that indicates a tendency of a left-to-right writing direction was in the condition of chirographic script presented in the writing sequence for 450 ms per stroke, exactly the same condition that was used by Tse and Cavanagh (2000). Even though a priming effect could not be excluded because each character was presented four times, the general pattern of results should not have been affected.[1] These results show that even the Chinese participants saw the right-to-left, stimulus-driven direction, just as the American participants did in Tse and Cavanagh (2000). In all the conditions with a short duration, the participants consistently perceived the stimulus-driven direction. When the duration was long enough, participants saw the writing direction only when rich writing clues were provided.

EXPERIMENT 2

In Experiment 1, the conventional writing sequence was assumed based on the researchers' own experiences. We used a questionnaire conducted by groups of participants in Experiment 2 to confirm the writing sequence. In so doing, the motion direction of the last stroke could also be examined again to confirm the results obtained in Experiment 1.

Method

The participants were 163 undergraduates, aged 19 to 28, from three classes of National Taiwan University and Jin-Wen Institute of Technology. All had more than 10 years of experience in writing Chinese characters.

The participants had to report their ages, the number of years they learned to write Chinese characters, and their seat positions in the classroom (row: front/middle/back, and side: left/right) in the questionnaire. Each questionnaire con-

[1] We do not think that a priming effect would change our conclusion for two reasons. First, the order of the trials and the trials assigned to which character were randomized, so the priming effect should be counterbalanced across participants. Second, even if some priming effect does exist, it should not have altered our pattern of results. The magnitude of the potential priming could be estimated by comparing our data with the data of Tse and Cavanagh (2000). The report from their Chinese participants, in a between-subjects design, is 0.5 after we dummy coded their data, and the report of the same condition in our within-subjects design is 0.34. Hence, the estimated priming effect in our experiment is 0.16. Adding 0.16 in the eight conditions does not change the perceived direction in any of the 45 ms conditions or in the 450 ms condition without any clues given (i.e., square script in a random sequence).

sisted of two parts. Part 1 consisted of an answer sheet for the experimental trials, and part 2 consisted of questions about the writing sequence and writing direction for the two characters, ''雪'' and ''彗''.

The participants viewed a similar presentation as in Experiment 1, but for the group test adopted in this experiment, two adjustments were made. First, all participants saw the same trial sequence. Second, only one of the two characters was presented in any one class, and as a result 130 participants (from two classes) saw the character ''彗'', and 33 participants (from one class) saw the character ''雪''. Because the character was projected on a big screen at the front of the classroom, and the participants' seats and the position of the projector differed for each class, perceived size of the character may have been different for each participant. In each trial, after the presentation had been completed, the participants wrote down the perceived direction of motion of the last horizontal stroke in part 1. These two characters were printed in part 2 of the questionnaire, and the participants had to label their strokes in the order in which they are accustomed to write them. After this, they had to choose the direction of their accustomed horizontal drawing, either left-to-right or right-to-left, and the direction of vertical drawing, either top-down or bottom-up.

Results and Discussion

The results of part 2 were analysed first. The data from two participants were excluded because their horizontal drawing direction was right-to-left. Another two were excluded because of missing data. Among the remaining 159 participants, the writing sequences of 128 participants (80.5%) were the same as in our writing sequence condition used in this study. The other 31 participants (19.5%) wrote stroke 11 as the 10th stroke, and stroke 10 as the 11th stroke. Since these 31 participants also wrote stroke 9 before stroke 11, their data were nevertheless included. These data show that the writing sequence assumed in Experiment 1 was consistent with the writing sequence obtained from the overwhelming majority in large groups of participants.

The data from the 159 participants were therefore further analysed as in Experiment 1, as shown in Table 2. The results for the characters ''彗'' and

TABLE 2
Mean of the dummy code values in each condition of Experiment 2

	Chirographic script		*Square script*	
Duration	*Normal sequence*	*Random sequence*	*Normal sequence*	*Random sequence*
45 ms	−0.42	−0.67	−0.69	−0.90
450 ms	0.13	−0.30	−0.21	−0.61

''雪'' showed no significant difference, $\chi^2(14) = 5.019$, $p = .986$, and the two data sets were collapsed. As in Experiment 1, the tendency to perceive the right-to-left direction was stronger in the square script (-0.60) than in the chirographic conditions (-0.31), $F(1, 158) = 47.79$, $MSE = 0.55$, $p < .0001$; stronger in the random sequence (-0.62) than in the writing sequence conditions (-0.30), $F(1, 158) = 67.21$, $MSE = 0.50$, $p < .0001$; and also stronger in the 45 ms (-0.67) than in the 450 ms conditions (-0.25), $F(1, 158) = 77.16$, $MSE = 0.74$, $p < .0001$. Unlike in Experiment 1, however, the two-way interaction of Sequence $\times$ Duration was significant, $F(1, 158) = 9.17$, $MSE = 0.298$, $p < .005$. Both in the writing and the random sequence conditions there was an effect of duration, ps $< .0001$, and both in the short and the long duration conditions, sequences (random or writing) did play a role, ps $< .0001$.

The interaction indicates that the participants had a high tendency to perceive the right-to-left direction when the stroke sequence was random or when the stroke duration was short; the tendency was even higher when the strokes were presented in random sequence at short durations. Despite the absence of such an interaction in Experiment 1, the general pattern of results in this experiment is essentially the same as in Experiment 1, showing that the participants consistently perceived the writing direction only when the character was in a chirographic script presented in a slow writing sequence.

GENERAL DISCUSSION

With native readers and speakers of Chinese as participants, our results replicated those of Tse and Cavanagh (2000) that Chinese and American participants do indeed perceive the last stroke in opposite directions. However, this is true only under very particular circumstances, when writing clues are available. In this study, we manipulated three factors, all of which proved to contribute to the perceived direction of the last stroke. The writing direction was inferred from the character script and the stroke sequence, and these, in turn, affected the perceived direction of motion, given a long enough exposure duration. When the character script or the presentation sequence do not provide enough writing clues, or when the exposure duration is too short, then even native Chinese readers perceive the right-to-left direction of the last stroke, just like the American participants of Tse and Cavanagh (2000).

This study reveals some of the top-down factors that can influence the perceived direction of the last stroke, namely: Character script and stroke sequence. The participants could not consistently perceive the direction of writing when no such clues were presented, even when the exposure duration was long. Although the entire character had been presented prior to the beginning of the trial, and the participants knew that it was a Chinese character before reporting the perceived stroke direction, their reports were not always consistent with the direction of

writing. That is, it is not the Chinese character *per se* that induced such apparent motion, rather, it is knowledge of how such a character is typically written that determines the top-down influence.

The apparent motion extending along the last stroke is similar to the illusory line motion reported by Hikosaka, Myauchi, and Shimojo (1993a), and they suggested that such motion was induced by an attention gradient. It has been shown that the time course of stimuli is an important factor in determining whether top-down or bottom-up effects are observed (Hikosaka, Myauchi, & Shimojo, 1993b; Steinman & Steinman, 1997; Steinman, Steinman, & Lehmkuhle, 1995; von Grunau, Dube, & Kwas, 1996). Accordingly, it is possible that attention allocation at different exposure durations was focused on opposite ends of the last stroke, and that this, in turn, induced opposite directions of apparent motion. Our participants, however, did not perceive directions of writing at long durations if the character was in square script or was presented in a random sequence. Since the script and the presentation sequence neither changed the stimulus arrangements, nor explicitly cued a location, it is hard to defend that the attention allocation in these conditions had been different.

Our data cannot be fully explained by transformational apparent motion either. The stimulus arrangement did not differ in any of the conditions in our study, but our participants nevertheless reported opposite directions of apparent motion under different conditions. Our participants perceived the left-to-right motion direction according to the writing clues provided by the handwritten-like stimulus when shown in a conventional writing sequence. The sequence was presented stroke by stroke, and all trials were randomized so that the participants could not predict, prior to the beginning of each trial, whether the sequence was the same as the conventional writing sequence or not. Thus, the perceived direction of motion should come from a dynamic mental representation (Freyd, 1987, 1993). Also, the dynamic representation takes time to develop, so that perceived writing direction was obtained only in conditions with long exposure duration. That is, in simulating the writing process by combing writing sequence, handwritten-like script and a long exposure duration, the perceived apparent motion direction was inferred from the direction of perceived action. A similar observation was found in Pascual-Leone, Dang, Cohen, Brasil-Neto, Cammarota, and Hallett (1995), who reported that mental practices of five-finger piano exercises rendered improvement similar to real, physical practices. Our results obtained with the chirographic script presented in the slow writing sequence support the hypothesis that there is a writing action in mind while viewing the presentation of the character on the screen.

In conclusion, this study answered the question of why the Chinese participants saw stroke directions opposite to the American participants in Tse and Cavanagh (2000). By presenting a chirographic script in a slow writing sequence, the presentation in their study activated a mental simulation of the real writing process, and thereby induced apparent motion in the writing direction.

When these writing clues are unavailable (i.e., in a square script, in a random sequence, or at short durations), then even Chinese readers do not perceive the writing direction.

REFERENCES

Anstis, S. M. (1980). The perception of apparent motion. *Philosophical Transactions of the Royal Society of London, Series B, Biological Sciences*, *290*, 153–168.

Babcock, M. K., & Freyd, J. J. (1988). Perception of dynamic information in static handwritten forms. *American Journal of Psychology*, *101*(1), 111–130.

Braddick, O. J. (1980). Low-level and high-level processes in apparent motion. *Philosophical Transactions of the Royal Society of London, Series B, Biological Sciences*, *290*, 137–151.

Ellis, W. D. (1938). *A sourcebook of Gestalt psychology*. New York: Humanities Press.

Flores d'Arcais, G. B. (1994). Order of strokes writing as a cur for retrieval in reading Chinese characters. *European Journal of Cognitive Psychology*, *6*(4), 337–355.

Freyd, J. J. (1983a). The mental representation of movement when static stimuli are viewed. *Perception and Psychophysics*, *33*(6), 575–581.

Freyd, J. J. (1983b). Representing the dynamics of a static form. *Memory and Cognition*, *11*(4), 342–346.

Freyd, J. J. (1987). Dynamic mental representations. *Psychological Review*, *94*(4), 427–438.

Freyd, J. J. (1993). Five hunches about perceptual processes and dynamic representations. In D. E. Meyer & S. Kornblum (Eds.), *Attention and performance XIV: Synergies in experimental psychology, artificial intelligence, and cognitive neuroscience* (pp. 99–119). Cambridge, MA: MIT Press.

Hikosaka, O., Myauchi, S., & Shimojo, S. (1993a). Focal visual attention produces illusory temporal order and motion sensation. *Vision Research*, *33*(9), 1219–1240.

Hikosaka, O., Myauchi, S., & Shimojo, S. (1993b). Voluntary and stimulus-induced attention detected as motion sensation. *Perception*, *22*, 517–526.

Klima, E. S., Tzeng, O. J. L., Fok, Y. Y. A., Bellugi, U., Corina, D., & Bettger, J. G. (1999). From sign to script: Effect of linguistic experience on perceptual categorization. *Journal of Chinese Linguistics*, *13*, 96–129.

Pascual-Leone, A., Dang, N., Cohen, L. G., Brasil-Neto, J. P., Cammarota, A., & Hallett, M. (1995). Modulation of muscle responses evoked by transcranial magnetice stimulation during the acquisition of new fine motor skills. *Journal of Neurophysiology*, *74*(3), 1037–1045.

Petersik, J. T., & Pantle, A. (1979). Factors controlling the competing sensations produced by a bistable stroboscopic motion display. *Vision Research*, *19*, 143–154.

Shiffrar, M., & Freyd, J. J. (1993). Timing and apparent motion path choice with human body photographs. *Psychological Science*, *4*(6), 379–384.

Steinman, B. A., Steinman, S. B., & Lehmkuhle, S. (1995). Visual attention mechanisms show a center-surround organization. *Vision Research*, *35*(13), 1859–1869.

Steinman, S. B., & Steinman, B. A. (1997). The line motion illusion: Visual attention or apparent motion? *Investigative Ophthalmology and Visual Science*, *38*, S372.

Ternus, J. (1926). Experimentelle Untersuchungen über phänomenale Identität [Experimental investigations of phenomenal identity]. *Psychologische Forschung*, *7*, 81–136.

Tse, P., & Cavanagh, P. (2000). Chinese and Americans see opposite apparent motions in a Chinese character. *Cognition*, *74*, B27–B32.

Tse, P., Cavanagh, P., & Nakayama, K. (1998). The role of parsing in high-level motion processing. In T. Watanabe (Ed.), *High-level motion processing—computational, neurobiological and psychophysical perspectives*. Cambridge, MA: MIT Press.

Tzeng, O. J. L., Hung, D. L., Chen, S., Wu, J., & His, M. S. (1986). Processing Chinese logographs by Chinese brain damaged patients. In H. S. R. Kao, G. P. van Galen, & R. Hoosian (Eds.), *Graphonomics: Contemporary research in handwriting* (pp. 357–374). North Holland: Elsevier Science Publishers BV.

von Grunau, M., Dube, S., & Kwas, M. (1996). Two contributions to motion induction: A pre-attentive effect and facilitation due to attentional capture. *Vision Research*, *36*(16), 2447–2457.

Manuscript received March 2002
Revised manuscript received October 2002