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Estimating the quantitative relation between incongruent information and response time

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Abstract

In Eriksen's flanker paradigm, participants' responses are slower and more error-prone when task-relevant and simultaneously available task-irrelevant cues are incongruent. The influence of task-irrelevant information decreases as its distance from the task-relevant information increases. Here, we manipulated the quantity of task-irrelevant information while keeping the distance constant. We asked whether when the impact on response selection processes was stronger the more incongruent information was available, or whether the impact on response selection depended only on its presence or absence. We conducted an experiment, in which subjects had to discriminate the direction of motion of a central point-light-walker that was flanked by two, four, or eight point-light-walkers at an equal distance from the center. The experiment showed that reaction times increased with the number of incongruent walkers. This effect was modulated by the total number of walkers, showing that the effect of incongruent information saturates when the display is cluttered.

PsycINFO classification: 2300; 2330; 2340; 2346

Keywords: Biological motion; Point-light-walker; Eriksen flanker interference; Incongruent information

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1. Introduction

Eriksen and Hoffman (1973) showed that to-be-ignored letters that flanked the target letter influenced a speeded discrimination response. The target letter was one of 12 letters positioned on an imaginary circle at an equal distance from the central fixation mark. The target letter was cued by a line and participants were asked to move a lever in one direction if the target letter was an H or an M and in the opposite direction if the target was an A or a U. The remaining 11 letters in the circular display were either all of the opposite (e.g., for the target H this would be A and U) or same response set (e.g., M for the target letter H), or only one of the 11 flankers was of the opposite response set. In addition to the number of incongruent letters, the distance between the target and the incongruent letter was manipulated. The results showed that the flanking targets from the opposite response set generally slowed responses and that the influence of incongruent information decreased with increasing distance between the single incongruent letter and the target. Further, response times were about the same when all letters were incongruent as when only one letter adjacent to the target was incongruent.

1.1. Distance vs. quantity in the Eriksen-flanker paradigm

Eriksen and Hoffman (1973) results suggest that only the distance from the letter and not the quantity of incongruent information is important. If the quantity had mattered, slower response times are expected with a display consisting of all incongruent elements compared to a display containing only a single incongruent element. However, the absence of a difference between the single incongruent and all incongruent conditions may have been due to the spot-like nature of attention (for an overview see Eriksen, 1995): only the target and some adjacent positions were treated up to the level of response selection, the remainder of the display was ignored. Thus, Eriksen and Hoffman's paradigm does not allow for the evaluation of the quantitative relation between incongruent information and response time because quantity and distance were confounded. To evaluate effects of the number of incongruent elements, the distance between the flankers and the target needs to be kept constant. Otherwise, the evaluation of the effects of adding incongruent elements is compromised by the fact that they are positioned outside the focus of attention.

In the present study, we disentangle distance and quantity by using a circular array of distractors and a central target. Under the assumption that participant's attention is focussed mostly on the central response-relevant target, the surrounding distractors should all be equally far or close to the attentional spotlight. Thus, the influence of the quantity or proportion of incongruent information can be assessed more directly. Further, we did not use letters as targets, but point-light-walkers. Thornton and Vuong (2004) showed that point-light-walkers produced flanker interference similar to letters even when the target was presented at central fixation.

In Thornton and Vuong's (2004) study, the walking direction of task-irrelevant peripherally located point-light-figures influenced the speeded discrimination of the direction of motion of a centrally presented point-light-walker. The target walker was flanked by two or four peripheral walkers that all faced and walked (in place) in the same direction. The direction of the peripheral walkers was either consistent or inconsistent with respect to the central walker. Participants were instructed to ignore the flanking (peripheral) walkers and to indicate the walking direction of the central walker by pressing a left or right key as quickly as possible. As expected, participants were unable to ignore the flanking stimuli. They responded much faster in conditions in which flanker and target were congruent than when the flanking walkers walked into the opposite direction. Thornton and Vuong reasoned that observers incidentally and automatically process biological motion up to a level where it influences action selection.

1.2. Possible quantitative relations between incongruent information and RT

In the study of Thornton and Vuong (2004), the correspondence relation between target walker and flanking walkers was manipulated in an all-or-nothing manner. Either all flanking walkers appeared to walk into the same direction as the target walker or all flanking walkers appeared to walk in the opposite direction. In the present contribution, we tried to quantify the effects of walker correspondence by manipulating the proportion of walkers that moved in the same direction as the target, as well as the number of walkers. At least two hypotheses with respect to the quantitative relationship between the amount of incongruent information and response times may be put forth. The all-or-nothing hypothesis holds that the amount of incongruent information does not matter: As soon as incongruent information is available it leads to a slowing of reaction times (RTs). Increasing the amount of incongruent information does not affect the response times any further. That is, the slowing of RTs should be the same with one incongruent walker as with for instance ten incongruent walkers. The alternative hypothesis of graduated slowing holds that the amount of incongruent information does matter, such that the more incongruent information is available the slower the response times will be. Among the large number of graduated relationships between RT and the amount of incongruent information, we chose to test two that have strong intuitive appeal.

First, it may be that RT increases linearly with the number of incongruent entities. That is, each time an incongruent entity is added, RT increases by a constant amount. In this model, the total number of entities available in the display plays no role. A testable prediction of this model is that a linear regression of RTs on the number of incongruent walkers should yield the same slopes regardless of the total number of walkers involved. For instance, if one incongruent walker incurred a cost of 50 ms, RTs would slow by 100 ms with two incongruent walkers, by 200 ms with four, and by 400 ms with eight relative to a condition without incongruent information.

Second, it may be that RT increases linearly with the proportion of incongruent entities. That is, the number of incongruent entities is evaluated with respect to the total number of entities in the display. This model would predict that the slopes derived from a linear regression of RTs on the proportion of incongruent walkers should be the same regardless of the total number of entities. For instance, if the RT increased by 100 ms between a condition with 0% incongruent flankers and a condition with 100% incongruent flankers, this would translate into an increase of 50 ms per incongruent walkers with a total of two flanking walkers, 25 ms with a total of four, and 12.5 ms with a total of eight.

1.3. The present study

To examine the validity of these two hypotheses and to quantify the relation between incongruent information and reaction times, we conducted an experiment with four between-subjects conditions using the paradigm of Thornton and Vuong (2004). Participants were asked to press a left or right key as fast and accurately as possible if the central walker appeared to walk to the left or right, respectively. They were instructed to ignore the flanking walkers. The number of flanking walkers is referred to as the display size. Note that by this definition, the display size does not include the central target walker. With a display size of two, two flanking walkers were presented to the left and right of the central walker (see Fig. 1). With a display size of four, one flanking walker was presented in each quadrant of the visual field, totaling four walkers. With a display size of eight, eight flanking walkers were presented on an imaginary circle around the central walker. The eccentricity of the flanking walkers was on the order of 5°: Five degrees with display sizes of two (also with a large walker) and eight, and 4° with a display size of four. Thornton and Vuong (2004) did not note any difference between eccentricities in this range. The flanking walkers could either walk in the same direction as the central walker (congruent walker) or in the opposite direction (incongruent walker). The number of incongruent walkers varied between 0, 1, and 2 with a display size of two, between 0, 1, 2, 3, and 4 with a display size of four and between 0, 2, 4, 6, and 8 with a display size of eight.

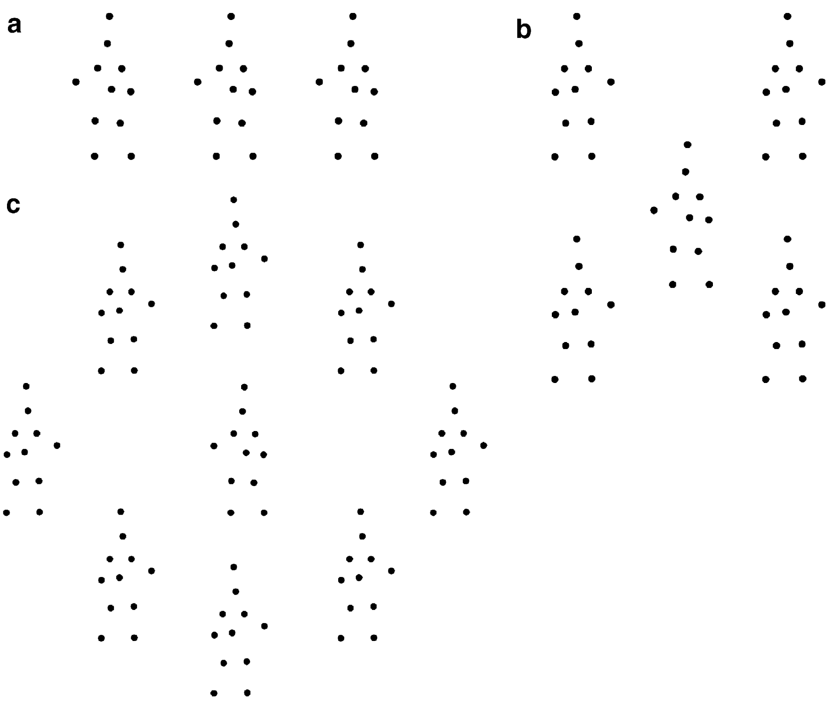

Fig. 1. Illustration of the stimuli. Panels a–c illustrate the stimulus arrangements with a display size of two, four, and eight flanking walkers, respectively. Participants were instructed to respond to the walking direction of the central target walker by pressing a left or right key as quickly and accurately as possible, while ignoring the flanking walker.

2. Method

2.1. Participants

University students were paid for their participation in single sessions of about 30 min. In most conditions, 12 participants were randomly assigned to each display size condition. Twelve students saw a display size of two (mean age = 25.3, SD ± 3.8; two men), 12 a display size of two with large walkers (mean age = 26.83, SD ± 3.8; three men), 11 a display size of four (mean age = 24.8, SD ± 3.6; two men) and 12 a display size of eight (mean age = 26.5, SD ± 3.6; six men). All participants reported having normal or corrected to normal vision, normal color vision, and no motor impairments. None of our participants were informed about the purpose of the present experiment until after the experiment and each participant took part in only a single experiment.

2.2. Apparatus and stimuli

Stimulus presentation and data acquisition were controlled by a PC equipped with a Matrox Millenium graphics adapter, permitting a pixel resolution of 1280 × 1024. Stimuli were presented on a 21-in. screen. Displays were updated at a rate of 87 Hz. The point-light-walkers were synthetically created by using a modified version of Cutting's (1978) classical point-light-walker algorithm. A set of 11 dots simulated a walker seen in profile. The dots marked the head, shoulder, elbows, wrists, hip, knees and ankles. The dots were always visible and did not disappear when they actually would be occluded by the walker's body. The walkers did not move across the screen, but walked in place with left or rightward orientation. Target and flanking walkers appeared simultaneously. The walker's starting phase was selected randomly on each trial and was equal for target and flankers. Each walker's stride cycle took about 960 ms and consisted of 40 different postures, each of which was shown for 23 ms. The size of each walker was 1.4° in width (left-to-right hand point along the x-axis at the most extended point of the step cycle) and 3.5° in height (head point to ankle points along the y-axis). Maximum stride width of each walker was about 1.4°. The target walker was always presented at the screen center.

2.2.1. Display size two

The flanking walkers were presented at an eccentricity of 5° to the left and right of the central walker. Throughout, the eccentricity of a walker is defined as the distance between the target's and flankers' hip dots.

2.2.2. Display size two, large walker

The size of the walkers was doubled to 2.8° in width and 6.9° in height. The target walker was presented at the screen center and the flanking walkers were at an eccentricity of 5° to the left and right of the central walker.

2.2.3. Display size four

Four flanking walkers were shown in addition to the central target walker: One walker was shown in each quadrant of the visual field at an eccentricity of 4° (hip-to-hip).

2.2.4. Display size eight

In addition to the central target walker, eight equally spaced walkers were shown with their hips aligned on an imaginary circle with a radius of 5°.

2.3. Procedure

The experiment took place in a dimly lit room. Participants sat at a distance of about 50 cm from the computer screen with their heads positioned on an adjustable chin rest. They were instructed to respond as quickly and accurately to the walking direction of the central target walker and to ignore the flanking walkers. The walker motion was shown for 1000 ms (about one complete stride cycle). Responses were made by pressing a left (Z on an American keyboard) for a target walker appearing to move to the left or right (?-/ on an American keyboard) key for a target walker appearing to move to the right with the corresponding index finger. The distance between response keys was 17.2 cm.

Responses with RTs longer than 1000 ms were regarded as missed trials, and responses shorter than 100 ms were regarded as anticipations. Pressing the wrong key was counted as a choice error. If the response was wrong, too early or too late, auditory and visual feedback was given, and the trial was recorded and repeated at some position in the remainder of the block.

2.3.1. Display size two

Participants worked through 45 experimental blocks consisting of eight trials in each block, preceded by about 15 practice trials. Each block was composed of the possible combinations of two walking directions of the target walker (or response locations, as each direction of target walker motion was associated with a different response key) crossed with the four possible combinations of the two directions of motion of the left and right flanking walkers, randomly intermixed. This resulted in twice as many trials with one incongruent walker compared to trials with zero or two incongruent walkers.

2.3.2. Display size four and eight

Participants worked through 45 blocks, consisting of 10 trials in each block, preceded by about 15 practice trials. Each block was composed of the possible combinations of two walking directions of the target walker (or response locations) and five numbers of incongruent flanking walkers (i.e., zero, one, two, three, four flankers were incongruent with respect to the target when the display size was four; and zero, two, four, six or all eight flankers were incongruent when the display size was eight), randomly intermixed. The assignment of walking direction to each of the four flanking walker positions was random.

3. Results

3.1. Results for each display size separately

Anticipations and missed trials (less than 1% throughout) as well as choice errors (2.9%, 1.9%, 1.4%, and 1.9% for display sizes of two, two with large walkers, four, and eight walkers, respectively) were excluded from the analysis. The percentage of choice errors did not

Table 1
Mean percentage of choice errors (the number of erroneous trials was divided by the number of retained trials and multiplied by 100) as a function of display size

Number of incongruent walkers	Size = 2	Size = 2, large walkers	Size = 4	Size = 8
0/0/0/0	1.8	1.1	0.5	0.9
1/1/1/2	2.2	1.7	1.0	0.9
2/2/2/4	4.9	3.0	1.2	2.3
–/–/3/6	–	–	1.3	2.6
–/–/4/8	–	–	3.0	2.8
Mean	2.9	1.9	1.4	1.9

The number of incongruent walkers varied between the display sizes. See text for details.

differ significantly between experiments (as evaluated by a between-subject, four-way ANOVA) and followed the mean response times (see Table 1). There was no indication of a speed-accuracy trade-off. Mean response times were calculated for each number of incongruent walkers and are graphed in Fig. 2.

3.1.1. Display size two

A one-way repeated-measures ANOVA revealed a significant effect of the number of incongruent walkers, $F(2,22) = 6.32$, $p < .01$, indicating that the more incongruent flanker were shown the slower were the reaction times. Paired-samples t-tests between adjacent numbers of incongruent walkers showed a significant difference between zero and one incongruent walker (425 vs. 433 ms), $t(11) = 2.77$, $p < .02$.

3.1.2. Display size two, large walkers

A one-way repeated-measures ANOVA revealed a significant effect of the number of incongruent walkers, $F(2,22) = 30.58$, $p < .001$, indicating that the more incongruent flanker were shown the slower were the reaction times. Paired-samples t-tests between adjacent numbers of incongruent walkers showed a significant difference between zero and one incongruent walker (423 vs. 441 ms), $t(11) = 6.36$, $p < .001$, and between one and two incongruent walkers (441 vs. 466 ms), $t(11) = 4.70$, $p < .001$.

3.1.3. Display size four

A one-way repeated-measures ANOVA showed a significant effect of the number of incongruent flankers, $F(4,40) = 23.52$, $p < .001$, indicating that the more incongruent flanker were shown the slower were the reaction times. Paired-samples t-tests between adjacent numbers showed a significant difference between two and three incongruent flankers (469 vs. 480 ms), $t(10) = 3.1$, $p < .02$, as well as between three and four incongruent flankers (480 vs. 495 ms), $t(10) = 5.57$, $p < .001$.

3.1.4. Display size eight

A one-way repeated-measures ANOVA showed a significant effect of the number of incongruent flankers, $F(4,44) = 7.83$, $p < .001$, indicating that the more incongruent flanker were shown the slower were the reaction times. Paired-samples t-tests between adjacent numbers showed a significant difference between four and six incongruent flankers (492 vs. 504 ms), $t(11) = 2.5$, $p < .03$.

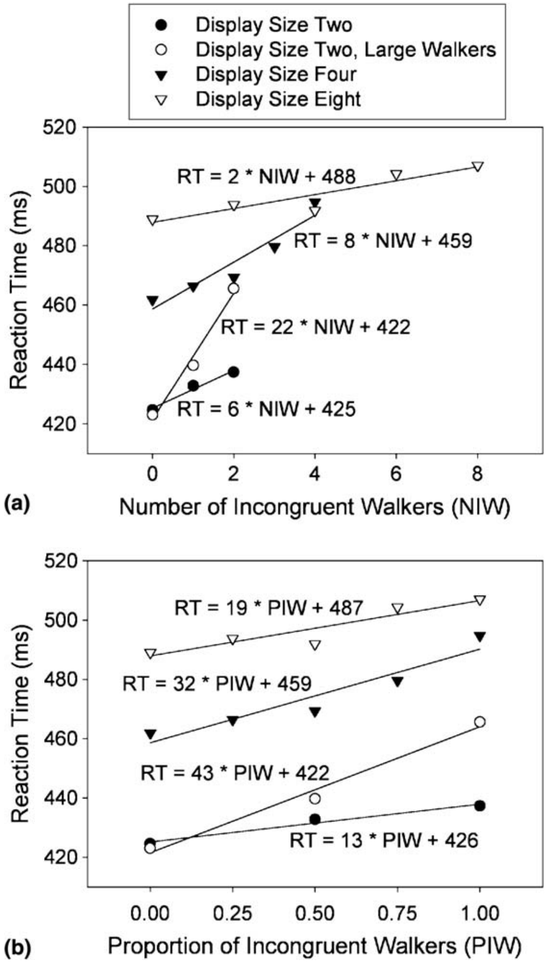

Fig. 2. Mean reaction time as a function of display size and number (panel a) and proportion (panel b) of incongruent walkers. Reaction times were regressed on the number and proportion of incongruent walkers. The best-fitting regression lines for each display size are shown. Slopes and intercepts are given in the equations next to the respective display size.

3.2. Comparison of display sizes

To compare the display sizes, we regressed response times on the number (between 0–2, 0–4, and 0–8 depending on the condition) and proportion (between 0 and 1) of incongruent walkers for each participant individually and subjected the resulting intercepts and slopes to between-subjects, one-way ANOVAs. The intercept of the regression gives an estimate of the effects of display size, that is, whether RTs were generally higher in a particular display size condition. The slope estimates effects of the quantity of incongruent information, that is, whether the slowing due to incongruent walkers was more pronounced for particular display sizes. Separate ANOVAs were run on the results of the regression on the abso-

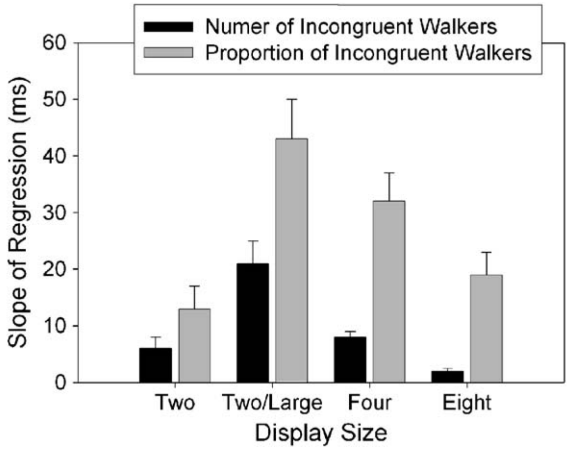

Fig. 3. Means and between-subject standard errors of a regression of reaction time on the number or proportion of incongruent walkers. The slopes (in ms) are reported for each display size. By *t*-test, all slopes were significantly different from zero (*p*s < .01).

lute number and proportion of incongruent walkers. Mean slopes and intercepts are shown in Figs. 2 and 3. First, we conducted ANOVAs on display sizes with equally sized walkers. To evaluate effects of the size of the walkers, we included the condition display size two, large walker in a second set of ANOVAs.

3.2.1. Display size two, four, and eight: number of incongruent walkers

Reaction times were regressed on the *number* of incongruent walkers (excluding display size two, large walkers). Slopes differed significantly as a function of display size, $F(2,32) = 4.07$, $p < .03$. Post hoc Scheffé-tests ($p < .05$ throughout) indicated that the slopes with a display size of four were significantly larger than with a display size of eight. Further, intercepts differed significantly as a function of experiment, $F(2,32) = 5.01$, $p < .02$. Post hoc Scheffé-tests showed that the intercepts were smaller with a display size of two than with a display size of eight.

3.2.2. Display size two, four, and eight: proportion of incongruent walkers

Reaction times were regressed on the *proportion* of incongruent walkers (excluding display size two, large walkers). Slopes differed significantly as a function of display size, $F(2,32) = 4.76$, $p < .02$. Post hoc Scheffé-tests indicated that the slopes with a display size of four were significantly larger than with a display size of two. Further, intercepts differed significantly as a function of experiment, $F(2,32) = 5.01$, $p < .02$. Post hoc Scheffé-tests showed that the intercepts were smaller with a display size of two than with a display size of eight.

3.2.3. Display size two, two with large walkers, four, and eight: number of incongruent walkers

Reaction times were regressed on the *number* of incongruent walkers (including display size two, large walkers). Slopes differed significantly as a function of experiment, $F(3,43) = 13.73$, $p < .001$. Post hoc Scheffé-tests indicated that the slopes with a display size of two and large walkers were significantly larger than the slopes in the remaining experiments. Further, intercepts differed significantly as a function of display size, $F(3,43) = 5.64$, $p < .01$. Post hoc Scheffé-tests showed that the intercepts were smaller with a display size of two (regardless of walker size) than with a display size of eight.

3.2.4. Display size two, two with large walkers, four, and eight: proportion of incongruent walkers

Reaction times were regressed on the *proportion* of incongruent walkers (including display size two, large walkers). Slopes differed significantly as a function of experiment, $F(3,43) = 6.42$, $p < .01$. Post hoc Scheffé-tests indicated that the slopes with a display size of two and large walkers were significantly larger than the slopes with display sizes of two and eight. Further, intercepts differed significantly as a function of display size, $F(3,43) = 5.64$, $p < .01$. Post hoc Scheffé-tests showed that the intercepts were smaller with a display size of two (regardless of walker size) than with a display size of eight.

4. Discussion

The aim of the present study was to investigate how the human visual system processes irrelevant incongruent information that may conflict with task-relevant information presented at the same time. Following the study of Thornton and Vuong (2004), we examined four conditions in which the amount of task-irrelevant incongruent information increased systematically within and across conditions. The experiments replicated the finding of Thornton and Vuong by showing that responses to a centrally presented right or leftward facing point-light-walker were influenced by incongruent point-light-walkers surrounding the target walker. Responses were faster when both the flankers and the target appeared to walk into the same direction than when the flanking walkers walked into a different direction.

4.1. Gradual but non-linear effects of the quantity of incongruent information

Further, we varied the amount of incongruent information such that a variable number and proportion of walkers walked into the same direction as the walker. Our results showed that reaction time slowed in a graduated manner as the quantity of incongruent information was increased. The graduated slowing was confirmed for all display sizes. These findings provide evidence for the hypotheses that the amount of incongruent information does matter and contradicts the hypothesis that processing of incongruent information is dichotomic, that is, reflects an "all-or-nothing"-phenomena. If this had been the case, a significant difference would have been expected between a condition with no incongruent walkers and the smallest number of incongruent walkers (i.e., one or two), but no further increase as the number of walkers was increased. This was clearly not the case (see t-tests between adjacent numbers of incongruent walkers). In contrast, our results are consistent with the idea that our visual system processes all given spatial information in parallel and makes an average before a certain response is selected. The more the average argues against the correct answer, the stronger is the interference effect (cf. Bundesen, 1990; Bundesen, Habekost, & Kyllingsbaek, 2005).

However, no clear answer can be given with respect to the exact relation between the quantity of incongruent information and RT. If the absolute number of incongruent walkers or the proportion of incongruent walkers was the only determining factor, main effects of display size should be absent in the respective regression analysis. For instance, if one incongruent entity had slowed down RTs by 10 ms, the slope should have been 10 ms in the regression of RTs on the number of incongruent walkers regardless of display size. Accordingly, the total increase should have been 20 ms with a display size of two, 40 with a display size of four, and 80 with a display size of eight. In contrast, if for instance 50% incongruent walkers in the total display had increased RTs by 10 ms, the slopes of the regression of RT on the proportion of incongruent information should have been 20 ms regardless of display size. This was not the case, however. The slopes of regressions of RT on the number and proportion of incongruent walkers varied as a function of display size.

The main effects of display size in both regression analyses suggest that the relation between the quantity of incongruent information and RT is non-linear. In both types of analysis (proportion/number), there was an advantage of a display size of four flanking walkers relative to one of the remaining display sizes. This suggests that incongruent information disturbs more when more entities are present (display size two vs. four), but that there is an upper limit of this increase (display size four vs. eight). The non-linear relationship between the quantity of incongruent information and RTs is further evidenced by the effect of walker size. The effect of incongruent information with a display size of two was more pronounced when the walkers were larger. One may resort to the ill-defined notion of saliency to explain these effects. Saliency may refer to the ease with which information is detected and extracted. Larger walkers were more salient and therefore had a stronger effect on RTs. The same idea may also accommodate effects of display size. With four walkers, the incongruent information was more salient than with just two walkers, however, increasing the number of walkers further led to a "crowding" of the scene that rendered the incongruent information less salient. The effect of crowding may also underlie the decrease in the overall level of RTs with a display size of eight. Eight walkers cluttered the visual display and made it more difficult to extract the task-relevant information. Note that the target walker was identical for display sizes two to eight, just the number of surrounding stimuli differed. In sum, there may be an optimal quantity of information that makes the incongruent information highly salient and at the same time avoids crowding.

4.2. Bundesen's theory of visual attention

Our results may be framed within the theory of visual attention proposed by Bundesen (1990). Bundesen assumes that the categorization of a stimulus element as belonging to a certain category is determined by the sensory evidence that an element belongs to the category, a perceptual decision bias associated with category and the attentional weight of the stimulus. The attentional weights are derived from pertinence values associated with a category. In the present case, the target has a higher pertinence value than the other elements in the display because its location is known. In the model, the speed of a perceptual discrimination is a function of sensory evidence in favor of a particular category, divided by the number of elements (number of targets plus weighted number of distractors) (Bundesen, 1990, p. 526). Thus, increasing the number of distractors (incongruent walkers) will increase the denominator and make the discrimination slower. This explains the gradual and non-linear decrease of reaction time with the number of incongruent walker as well as the general slowing of response times with the total number of elements (for similar results see Eriksen, 1995; Eriksen & Hoffman, 1973).

However, the shapes of our non-linear functions are somewhat at odds with the model. Following Bundeson, effects of incongruent information are expected to decrease as the limits of working memory (about four items) are approached. That is, the effect of incongruent information is expected to asymptote when three incongruent walkers are presented. This is not the case; quite to the contrary, inspection of Fig. 2 shows that the effects of irrelevant information increase slowly first and more rapidly with about 3–4 incongruent walkers. Also, effects of incongruent information are obtained with more than four elements in the display. The *t*-tests show differences between three and four (display size four) and four and six (display size eight) numbers of incongruent walkers. Because the target walker has to be added, more than four walkers were treated in these conditions. This is somewhat beyond the current estimates of working memory (four items).

4.3. Kornblum's dimensional overlap model

The most prominent model within the context of interference paradigms is the dimensional overlap model developed by Kornblum, Hasbroucq, and Osman (1990). This model argues that any (task-irrelevant) feature (dimension) of a stimulus may automatically activate a certain response whenever there is a dimensional overlap between stimulus and response features. In parallel, the task-relevant information is being processed which leads to a controlled response selection. Finally, the results of the two processes are then compared on a verification level. If the automatic and controlled-response selection processes lead to the same result, the response is immediately executed. However, if not, the time-consuming conflict must be solved before the response can be executed. Implicitly, this model assumes that the task-irrelevant stimulus dimension can either be overlapping or non-overlapping. Stimulus response overlap leads to response facilitation, non-overlap leads to response interference. However, the results of the present study suggested that task-irrelevant directional information is averaged to some degree before it reaches the stage of response selection. Thus, the strength of the task-irrelevant activation depends on how much incongruent information is present in a display.

4.4. Relation to studies with static stimuli

Finally, one may consider the relation between dynamic and static stimulus–response compatibility. Most of the previous work on stimulus–response compatibility has focussed on position information (e.g., Hommel, 1993; Hommel & Lippa, 1995; Rubichi, Nicoletti, Iani, & Umilta, 1997; Simon, 1969) (for exceptions, see Bosbach, Prinz, & Kerzel, 2004; Bosbach, Prinz, & Kerzel, 2005a, Bosbach, Prinz, & Kerzel, 2005b; Ehrenstein, 1994; Michaels, 1988, 1993; Proctor, Lu, Van Zandt, & Weeks, 1994). The amount of available (and irrelevant) position information is somewhat harder to vary than the number of incongruent walkers in the present study. One possibility is to vary the number of reference frames of a stimulus position (Lamberts, Tavernier, & D'Ydewalle, 1992). For instance, a target may be presented in the left or right visual field and in each of the two hemifields, two positions are possible. The two visual fields and the two possible positions in one hemifield create references frames. Thus, a stimulus could be presented to the left of fixation and in the leftmost position in which case both reference frames are congruent. Or it could be presented on the left visual field in the right position in which case the two reference frames are in conflict. Effects of both reference frames on manual choice RT have been observed, and the effects were additive. This corresponds with the present observation that the more incongruent information is present, the more RTs are slowed. To our knowledge, however, no study has manipulated the number of reference frames (which corresponds to effects of display size in the present study) and evaluated whether effects of incongruent information increases or decreases. The present study shows that there is no simple answer to the question of how the number of stimuli and the effects of incongruent information are related because a number of factors such as saliency (determined by size, crowding, etc.) intervene.

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