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The Effectiveness of Cue Relevance and Saliency in the Context-Specific Proportion Congruent Effect

Abstract*: The context-specific proportion congruent (CSPC) effect can be observed when within a block of trials two different ratios congruent-to-incongruent trials are assigned to different variants of stimulus feature (like location or colour). This feature is a contextual cue. CSPC effect is present when congruency effect size is differentiated according to the ratio congruent-to-incongruent trials assigned to specific stimulation parts.*

In the present paper the relevance and saliency of contextual cues in variants of the flanker task were systematically manipulated, by varying background colour, stimulus colour and luminance, and target-arrow direction as contextual cues. The obtained results support the claim that task-relevancy of the contextual cue is a critical factor in predicting its effectiveness (no CSPC effect for task-irrelevant background, stimuli colour or luminance, and significant CSPC effect for task-relevant target-arrow direction).

Key words: *conflict, proportion congruent, cognitive control, relevancy*

INTRODUCTION

When we perform an intended action toward a target object (for instance we name the shape of it), irrelevant target features or accompanying objects (for instance other shapes surrounding the target) can either support this action or interfere with it. Responses are faster and more accurate when both features/objects relevant to the task and irrelevant to the task are associated with the same response (a congruent trial). More delayed responses and higher error rates are observed on incongruent trials where both the relevant and irrelevant object dimensions or target and flanking objects are associated with alternative responses. This difference between performance on congruent and incongruent trials is called ‘a congruency effect’ or simply ‘interference’.

To investigate it extensively, so-called interference paradigms have been employed. Classic examples are the Stroop task and the Eriksen task, although research has been carried with numerous analogs. In the Stroop task, the words describing colours are displayed in different colour inks (for example the word RED appears in green) and the ink colours in which the words are presented should be reported; the content of the word (highly salient dimension) has to be ignored as irrelevant to successful task performance (Stroop, 1935). In the Eriksen task, which was used in the present study, the participants have to respond to a relevant central target stimulus and ignore irrelevant flanker stimuli (Eriksen & Eriksen, 1974).

Because of strong response tendencies automatically evoked by irrelevant parts of the stimuli, effective implementation of cognitive control is an essential aspect of performance in the interference paradigm. This allows successful performance of the intended action, although interference results in clear effects on performance measures.

Such interference, or congruency effects can be, however, reduced if the level of cognitive control is increased. This is the case if the probability of incongruency is high (Botvinick, Nystrom, Fissell, Carter, & Cohen J.D., 1999; Gratton, Coles, & Donchin, 1992). The most extensively mean used to manipulate this probability is changing the congruent-to-incongruent trial ratio over the whole session (called in the present paper just ‘*ratio*’ or

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'*proportion congruent*'). The congruency effect is reduced when the percentage of congruent trials is low in a block, while the congruency effect is enhanced when the majority of trials in the block are congruent. Such a pattern of results has been repeatedly shown for various interference paradigms: flanker task (Gratton et al., 1992; Bartholow, Pearson, Sher, Wieman, Fabiani, & Gratton, 2003; Casey, Thomas, Welsh, Badgaiyan, Eccard, Jennings, & Crone, 2000; Mattler, 2006; Żurawska vel Grajewska, Sim, Hönig, Herrnberger, & Kiefer, 2011), Stroop and Stroop-like tasks (Logan & Zbrodoff, 1979; Logan, 1980; Kane & Engle, 2003; Carter, MacDonald, Botvinick, Ross, Stegner, & Noll, 2000; Bélanger, Belleville, & Gauthier, 2010; Merikle & Joordens, 1997; Bugg, Jacoby, & Toth, 2008; Experiment 2 in Fernandez-Duque & Knight, 2008), and in the others (Hommel, 1994; Stürmer, Leuthold, Soetens, Schröter, & Sommer, 2002; Funes, Lupiánez, & Humphreys, 2010; Toth, Levine, Stuss, & Oh, 1995; Hantsch, Jescheniak, & Schriefers, 2009; Johnson & Yantis, 1995). This ratio effect can be interpreted as a result of changes in the cognitive control level, and is claimed to reflect the participants' ability to adjust their cognitive control in order to optimize their performance.

Recent results have shown that such the adjustment of cognitive control levels can be even more flexible. The ratio effect can occur even if the overall proportion of congruent trials is 50% across the experiment if particular parts of stimulation are presented with two different proportions congruent. For example, Corballis and Gratton (2003) presented a target letter (H or S) flanked by the congruent letters (i.e. HHHHH, SSSSS) or the incongruent letters (i.e. HHSHH, SSHSS). Letter arrays were presented on the right or on the left. Stimuli were 75% congruent when presented on the right side of the screen, but only 25% congruent for arrays presented in the left visual hemifield. Altogether, the overall ratio within a block was 50%. Nevertheless, the size of the congruency effect was strongly dependent on the ratio at the given location and was not influenced by the ratio applied at the opposite hemifield (Corballis & Gratton, 2003).

Similar rapid changes in the cognitive control level within a block were also shown in the Stroop task. Crump, Gong and Milliken (2006) asked participants to name the colour of rectangle preceded by a colour word in white (RED, GREEN, BLUE, YELLOW). The colour word prime was presented centrally and the coloured rectangle appeared above or below the fixation point. One of possible target locations was associated with a high percentage of congruent trials (75%) while the other with a low percentage of congruent trials (25%). Although the overall ratio in the experiment was 50% congruent overall, the interference effect was larger for the location with a higher percentage of congruent trials (Crump, Gong, & Milliken, 2006). The authors called this effect as the *context-specific proportion congruent effect* (CSPC), where two different locations were defined as two contexts, because of certain proportion of congruent trials was associated with each of them. The location served here as a contextual cue.

An interesting question arises: what stimulus dimensions can effectively serve as contextual cues? Are all cues equally effective in evoking the contextual effect? In the present paper for the first time some cue's characteristics were systematically varied and the effectiveness of such cues were examined.

According to 'the relevancy for the task hypothesis', the feature serving in a given task as the contextual cue can be effective, if it is in any way relevant for the task. In line with the *contingent involuntary orienting hypothesis* proposed by Folk and colleagues (Folk, Remington, & Johnston, 1992), involuntary processing of non-target object or feature is possible especially when it is similar to properties looked for observer (like colour in the Stroop task or spatial location in the Eriksen task).

Lehle and Hübner (2008) found colour as ineffective contextual cue in their version of the flanker task (the participants had to judge the parity of a central digit flanked by other digits), and concluded, that hue can be readily used as a basis for adjusting of cognitive control only in a task where the colour is a crucial dimension like in the standard Stroop task (Lehle & Hübner, 2008).

This claim seems to be supported by a recent study by Crump, Vaquerro and Milliken (2008). First, it was shown that shape is not an effective contextual cue in the Stroop task (Crump et al., 2006). Either a circle or a square, the colour of which was to be named, followed a colour word. Each shape was associated with different congruency ratios. The interference effect was not seen to differ for the two shapes. Crump et al. (2008) showed that for shape to act as an effective contextual cue it was necessary for the shape dimension to be in some way relevant to the task, for example, when participants had to not only name the colour on each trial but additionally report the number of squares that had appeared during the experiment (Crump, Vaquerro, & Milliken, 2008).

The results described above suggest that factors crucial for the task can act effectively as contextual cues. On the other hand, however, the very same authors who claimed task-relevancy as crucial in the CSPC effect, demonstrated stimuli location, the dimension irrelevant for the Stroop task, acting as effective contextual cue in the colour-naming task (Crump et al., 2006; Crump et al., 2008; Crump & Milliken, 2009). Crump et al. (2006) assumed, this conflicting result appeared because the priority of stimulus location processing (for other evidences for location special status see also: Logan & Zbrodoff, 1979; Logan, 1980; Simon, 1990).

Thus, another factor seems to be important: relative saliency of the feature used as contextual cue. According to the 'relative saliency claim', very salient features, even if task-irrelevant can act as efficient contextual cues. This factor can help to account not only Crump et al. (2006) result (location in the Stroop task), but another conflicting data reported by Vietze and Wendt (2009): the colour as effective contextual cue in the Eriksen task. The hypothesis of the relative saliency role is complementary for the task-relevance claim rather than being in opposition to it.

On balance, the boundary conditions for evoking the context-specific proportion congruent effect remain undefined. The present paper aimed to clarify these issues. Specifically, the task-relevancy and the relative saliency of the feature used as the contextual cue were tested to establish whether they are good predictors of cue effectiveness in evoking the CSPC effect. To this end, the task-relevancy of the feature used as the contextual cue as well as its saliency were manipulated. Four different types of contextual cues were tested across three experiments. Cues varied from fully irrelevant to highly relevant in the flanker task that was presented. Their task-relevance was changed gradually from Experiment 1 to Experiment 3. Additionally, contextual cues differing in their relative saliency were compared. The saliency of a given feature was defined here as the degree of ease of feature processing and the likelihood of attentional capture by this dimension. The present study for the first time systematically examines the task-relevancy of contextual cue across numerous experiments, controlling the task difficulty and relative saliency of the cue. Some factors never examined in the contextual cue role were used.

Overview

In Experiment 1, the background colour as a contextual cue was tested. The background colour was irrelevant to the task throughout and the saliency of the feature was rather low due to a natural tendency to ignore a background. No CSPC effect in Experiment 1 was expected.

More salient, although still task-irrelevant features were employed in Experiment 2: stimulus colour and luminance (black and white stimuli in the latter case). According to the claim recognizing task-relevancy as crucial, in both sessions of this experiment (a colour session and a luminance session), no CSPC effect should occur. On the other hand, the hypothesis of a role for relative saliency, supported by demonstration of colour cue effectiveness in the flanker task (Vietze and Wendt (2009)), led us to predict a CSPC effect here. In line with the relative saliency role assumption, the CSPC effect should be even stronger in the luminance session. Since luminance could be more easily detected than the stimuli colour, and was analyzed at an even lower level of processing than hue (thus, was more salient than colour), it should provide better contextual cuing than colour.

This prediction can be also drawn from Kasten and Navon study (2008), where spatial cuing was employed. The central cue (arrow) was incorrect on 1/6 of trials. On all incorrectly cued trials, an additional cue appeared: either a small pink square displayed peripherally or as a pink colour of the arrowhead (part of the central cue; on remaining trials the arrow was uniformly white, presented against a black background). Although pink hue appearance was perfectly informative, participants benefited on it only when appeared as the arrowhead colour. Thus, participants were able to learn contingency or use secondary cue information only when it was presented in the attentional focus (Navon & Kasten, 2008). Similarly, changes of the target and flankers' colour or luminance can easier exert any effect as appearing in the centre of participant's attentional focus.

Finally, in Experiment 3, the most relevant feature for the flanker task, i.e. stimulus identity, served as a contextual cue. More precisely, the arrows pointed to the left or to the right were associated with one proportion congruent, while the arrows pointed up or down were assigned to the reversed ratio. Since a highly relevant feature was used here as a contextual cue, we expect a CSPC effect in Experiment 3.

In all experiments arrows served as target and flankers; participants had to determine the identity of a central character while ignoring the flanking characters.

EXPERIMENT 1: BACKGROUND COLOUR AS CONTEXTUAL CUE

In Experiment 1 participants responded to the central target (arrow) surrounded by four arrows pointed to either the opposite direction (on incongruent trials) or to the same direction as the target (on congruent trials). Simultaneously with the onset of five arrows, the background colour was changed from grey to either red or green. Participants were carefully informed about the background colour – proportion congruent (ratio) contingency. For half of them, when the background was red, the probability of a congruent trial was only 25% and the probability of an incongruent trial was 75%. The green background was assigned to the opposite ratio: 75% congruent and 25% incongruent.

Changes in the background colour were highly visible, but fully irrelevant to the task. It could be expected that because of its irrelevancy, such a feature would not be an effective contextual cue. In addition, to prevent a difference in the ability to discern the arrows when presented against different backgrounds, stimuli were always displayed against a black square approximately 4x4 degrees, located centrally. We therefore prevented turning the contextual cue from the intended 'background colour cue' into a 'visibility and background colour cue', but as additional effect the changing background colour was rendered even easier to ignore and further from the attentional focus.

Although ineffectiveness of the contextual cue used in Experiment 1 was expected, one could argue that the opposite results are also possible or even likely. Since Bugg et al. (2008) demonstrated that a font type can be an effective contextual cue in the Stroop task, and the font was not only fully irrelevant for the task, but also not salient (difference between the Arial and Bookman Old Style fonts used in the study is modest), one can expect that a much more detectable feature as the colour of the background tested in Experiment 1 can play the role of a contextual cue effectively. If this were the case, an enhanced flanker effect for one hue of background (associated with 75% ratio congruent) and a reduced effect for the other background colour (associated with 25% ratio congruent) is expected. A lack of the CSPC effect would be demonstrated by equal congruency effects for both contexts.

Method

Participants

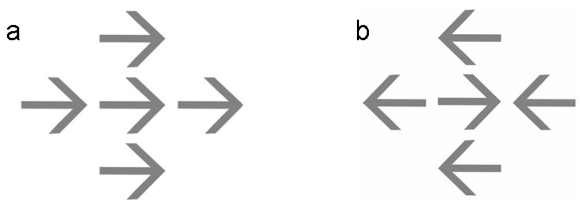
Participants in all experiments were undergraduate psychology students at the University of Finance and Management in Warsaw or of other universities in the area. All had normal or corrected-to-normal vision. None of them had participated in a similar experiment before. Subjects obtained course credit for participation.

There were 22 participants in Experiment 1 (2 male), the age ranged between 19 and 51 (mean age: 22.2); 20 of them were right-handed (self reported). Two further persons took part in Experiment 1, but their data were discarded, due an accuracy rate below 75% in at least one condition. This exclusion criterion was used in all experiments.

Stimuli, procedure and apparatus

Participants responded to the arrow presented at the central fixation point with their dominant hand. They pressed the left-arrow key of a standard keyboard when the arrow pointed to the left and the right-arrow key when the target arrow pointed to the right. Speed and accuracy were equally emphasized. There were four flanker arrows (Figure 1). They surrounded the target arrow: one was situated above, one below, one on the left and one on the right. The flanking arrows could point to the right or to the left. On the incongruent trials all flankers pointed to the direction opposite to the pointed by the target. On congruent trials all four flanking arrows and the target pointed to the same direction.

Figure 1. Stimulus displays used in Experiment 1 and 2. (a) Example of a congruent stimulus and (b) an example of an incongruent stimulus. Participants had to respond according to the central arrow direction. In Experiment 1 arrows were grey and were presented against a black square (fitted in size to the stimulus). In Experiment 2 arrows were green or red and presented against the grey isoluminant background (colour session) and black and white against grey background (luminance session).



The arrows were uniformly grey. The single arrow could be fitted to 1 cm x 1 cm square, equivalent to a visual angle of 1 degree at the viewing distance of ca. 60 cm. The target and flankers were presented against black square of approximately 4 x 4 cm (4 x 4 degrees of visual angle), fitted to the array size. Stimuli were presented for 409 ms. The black square was presented on a grey background. Simultaneously with array onset, the 'outer' part of the background changed its colour from grey to red or green (unpredictably) and stayed as long as the stimuli. The red, green, and grey backgrounds as well as the grey arrows were isoluminant. The trial response triggered a 605 ms delay, followed by the next trial. A small black square of approximately 1 degree served as a fixation point and was presented centrally on the screen. This was removed when arrows were presented.

For half of participants the red background was associated with the 25% ratio (25% congruent trials and 75% incongruent trials), and the green background with the 75% ratio (75% congruent trials and 25% incongruent). For the other half of participants it was reversed: the red background was assigned to the 75% ratio and the green one with the 25% ratio. The ratio across entire experiment was 50%. Participants were informed of this contingency and the information was repeated between sessions.

There were 640 trials in the experiment. On 50% trials (i.e. 320 repetitions) the red background was presented and on 50% trials the green background was presented, varied randomly. There were 80 congruent trials and 240 incongruent trials within the 25% ratio. Consequently, within the 75% ratio context, there were 240 congruent trials and 80 incongruent ones. For each of the groups, half of trials contained the target arrow pointed to the left and the other half contained the right-pointing target arrow.

Participants were tested individually in a sound-proofed, dark room with a standard PC computer. First, the demo version of the task, identical to the main task, but shorter, were presented. Instruction to press left and right arrow keys as fast and as accurately as possible according to the target arrow direction was given, as well as precise information about the background colour – ratio congruent contingency. Note, however, that red or green background were displayed simultaneously with arrows, thus participants could not prepare themselves for a certain stimuli congruency. After a short training block, the first session, lasting about 8 minutes, started. A second, identical session was performed after short break, while the instructions and information about the colour – ratio contingency were repeated.

The stimuli were presented on a 22-inch CRT monitor with a 120 Hz refresh rate, situated about 60 cm from participant. Stimuli were designed and presented using Presentation software (v. 12.1, Neurobehavioral System Inc.) which also collected response data.

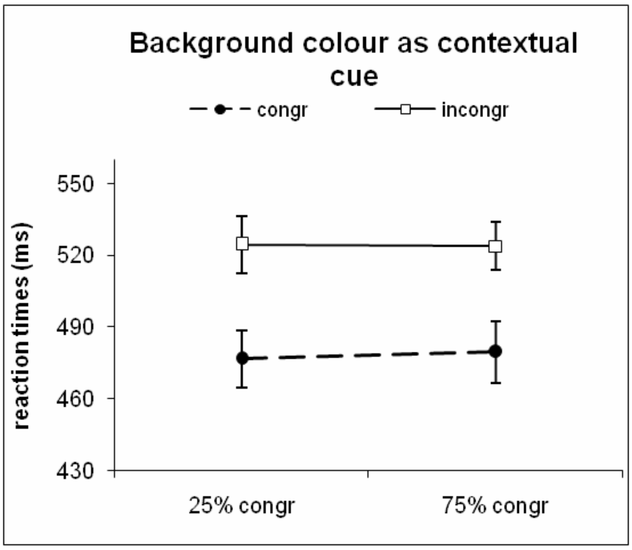
Mean reaction times (RT) were calculated with exclusion of incorrect responses and these reaction times which were shorter than 200 ms and longer than 1500 ms. Responses outside this response window were considered as errors.

The reaction times data and the error rate data were submitted to a 2 (Ratio: 25% vs. 75%) by 2 (Congruency: congruent vs. incongruent) repeated measures ANOVA. The assignment of a given ratio to one of two possible background colours was the between-subject factor. The same statistical analysis method and the same variables were used for each experiment of the present study (background colour was replaced with a specific contextual cue used in the experiment).

Results

Mean reaction times were shorter for congruent than incongruent trials: 478 ms vs. 524 ms; main effect of Congruency: $F(1, 20) = 179.5$, $MSE = 259$, $p < 0.001$, $\eta^2 = 0.9$. More interestingly, the flanker effect was slightly larger for the 25% ratio than the 75% ratio (48 ms vs. 44 ms), but the Ratio x Congruency interaction was not significant; $F(1, 20) < 1$ (Figure 2).

Figure 2. Results of Experiment 1. Mean reaction times on congruent trials (dashed line, the circle black markers; congr) and on incongruent trials (solid line, the square white markers; incongr) as a function of proportion congruent signalled by background colour. congr = congruent; incongr = incongruent; 25% congr = 25% congruent trials and 75% incongruent trials; 75% congr = 75% congruent and 25% congruent trials.



One could assume that such a background colour – ratio contingency was able to exert its effect on performance only after experiencing it throughout a longer session. Due to this, a further analysis was confined to the second session: there were 40 trials in the less frequent conditions at each context, while first block of 320 trials was turned into a learning phase. For this time window the flanker effect for both ratios was 44 ms, thus participants did not associate the context and expected congruency even after more than 320 trials of training.

Similar to the reaction time pattern, error rate analysis of both sessions averaged, revealed a significant main effect of Congruency with more frequent errors for incongruent than congruent trials: 10.3% vs. 3.2%; $F(1, 20) = 49.9$, $MSE = 0.002$, $p < 0.001$. There was no difference in the flanker effect size (for 25% ratio and 75% ratio: 6.9% vs. 7.4%, respectively).

Although analysis of reaction times showed no main effect of Ratio nor of the between-subject factor 'Colour-ratio assignment', these two factors interacted significantly: $F(1, 20) = 7.6$, $p = 0.01$. Closer inspection of this interaction revealed that both subgroups' reaction times were influenced by ratio in different ways. For the first group (who experienced 25% ratio when the background was red and 75% ratio when it was green) reaction times were shorter for the 25% ratio than the 75% ratio (478 ms vs. 486 ms; significant main effect of Ratio: $F(1, 10) = 13.3$, $MSE = 53$, $p = 0.004$). In contrast, for the other subgroup the difference was not significant $F(1, 10) = 1.7$, $MSE = 230$, $p = 0.2$ and mean reaction times were longer for 25% ratio than 75% ratio (523 ms vs. 517).

Discussion

The background colour, changed concurrently with stimulus display, was easy to detect and analyze. It could be supposed that such enormous change in stimulation can be easily used to optimize performance in the flanker task by adjusting flanker processing according to the probability of flankers' congruency. Participants also reported the change as highly visible, but also stated that they tended to ignore this cue. As a result real saliency was low, what is also in line with the fact, a background is by definition attended much less than other elements of the visual scene (Busswell, 1935). These self-report claims and background's role estimation were confirmed by the data. There was no difference in flanker effects between both ratios distinguished by red vs. green background colour. Moreover, the analysis confined to the second session results showed no learning effects.

This pattern of results supports the statement that the relevance for the task is a crucial predictor of contextual cue effectiveness and could also extend to the attentional aspect: dimensions which are not likely to attract attention (not salient) cannot effectively modulate task performance.

It is also in line with Kasten and Navon study (2008), described in the Overview. In this spatial cuing task, pink colour always accompanied incorrect cue. In spite of high informative value of this additional cue, observers benefited on it only when displayed as colour of the central arrow and completely ignoring it when pink hue appeared in a form of the small peripheral square (Navon & Kasten, 2008). If learning contingency or using secondary cue information is possible only when it is presented in the attentional focus, the CSPC effect is probable in Experiment 2, when task-irrelevant contextual cue – colour or luminance - is feature of the target and flankers remaining in the centre of the attentional focus.

Clearly, if the feature is relevant for the task, it is also in attentional focus and its relative saliency is higher. The background colour used as the contextual cue in Experiment 1 was both irrelevant for the task and out of the attentional focus. Consequently, the results confirmed both claims defining what is necessary for effective cueing: attentional focus (Navon & Kasten, 2008), as well as the relevance of feature used as contextual cue (Crump et al., 2008). In Experiment 2, stimulus colour or luminance as contextual cues were examined: both irrelevant for the task, but situated in the centre of attentional focus and consequently much more salient.

EXPERIMENT 2: STIMULI COLOUR AND LUMINANCE AS CONTEXTUAL CUE

Although a number of studies have confirmed that the task-relevance of a feature used to indicate a certain ratio in the flanker task is crucial, conflicting data has also been obtained. Vietze and Wendt proved that the colour of characters in the classic version of the flanker task can be an effective contextual cue, in spite of its irrelevance for letter discrimination (Vietze & Wendt, 2009). Speculating on the reasons for this effect, one can claim that colour is a very salient feature, i.e. is processed on low level. As an elementary feature, colour may fulfill the role of contextual cue effectively. Though inconsistent with a task-relevancy claim, this result can corroborate the relative saliency role assumption. The relative saliency role was tested in Experiment 2 by directly comparing the colour in the contextual cue role with an even more salient dimension: luminance (black vs. white signs) in the contextual cue role. Hue and luminance were introduced as the contextual cue in two separate sessions.

Luminance was assumed to be more salient because brightness is decoded earlier in processing visual stimuli, as well as more easily and faster than colour. This was posited in theoretical approach of visual scene processing hierarchy by David Marr (1982) and suggested by the visual search experiment conducted by Theewes and Kooi (1994). They demonstrated a clear size set effect for a colour and shape conjunction visual search and a lack of the size set effect for contrast and shape conjunction (black or white signs were used). Thus, assessing whether object is black or white and connecting it with shape occurs at earlier, preattentional stage (Theeuwes & Kooi, 1994). As a result, luminance is named more salient and according to the relative saliency hypothesis, in the present experiment could be a more powerful cue for distinguishing contexts.

All stimuli and the background in a 'colour session' were isoluminant, to examine solely hue effect in the absence of luminance changes. Stimuli used in Experiment 2 were identical to those used in Experiment 1 (apart from the colours of the arrows and background). Participants were again informed in detail about ratio – colour/luminance contingencies, but as no cue appeared before the target, participants were not able to prepare themselves for the more probable congruency.

Method

Participants

There were 24 participants in Experiment 2 (1 male), the age ranged between 19 and 49 (mean age: 26.5 years); all of them were right-handed (self reported). Two further persons took part in Experiment 2, but their data were discarded, due to the percent correct rate lower than 75% in at least one condition.

Stimuli, procedure and apparatus

All experimental settings were the same as those in Experiment 1 with the following exceptions. The background was uniformly grey throughout the entire experiment. Colour and luminance of arrows rather than the background was changed to create different contexts. There were two separated sessions in Experiment 2: a colour session and a luminance session. Two different ratios (25% congruent vs. 75% congruent) in the colour session were assigned to different colours of arrows. Isoluminant red and green hues were used and on each trial all five arrows (the target and four flankers) were presented in a given colour. In the luminance session, for half of the participants black arrows were associated with the 25% ratio, while white characters were associated with the 75% ratio. There ratios were reversed for the other half of the participants. The order of sessions and assignments were fully counterbalanced.

The target and flankers were presented for about 208 ms. Responses triggered the next trial following a 1210 ms delay.

Due to testing two candidates for contextual cue within one experiment, number of trials per condition had to be reduced (when compared with Experiment 1). Altogether, there were 800 trials in Experiment 2, 400 trials for the colour session and 400 trials for the luminance session. Unlike Experiment 1, in the present experiment both sessions were divided into two unequal blocks: first, a shorter block comprising 80 trials and second, a longer one, comprising 320 trials. The first, short block was excluded from analysis. As a result, there were 320 trials per each session included in the analysis. Considering the luminance session as an example, 160 trials contained black stimuli and 160 trials contained white stimuli. 25% of trials with black stimuli were congruent (40 trials), while 75% were incongruent (120 trials). 75% of trials with white stimuli were congruent (120 trials) and only 25% were incongruent (40 trials). The entire experiment lasted about 25-30 minutes.

All other experimental settings were identical with these used in Experiment 1.

The data were submitted to a repeated measures ANOVA with variables common for all experiments, i.e. Ratio and Congruency. One additional within-subject factor was Session (luminance vs. colour).

Results

The response times averaged across both sessions were shorter in the luminance session than in the colour session (486 ms vs. 503 ms); the between-subject factor 'Session' was significant: $F(1, 20) = 5.2$, $MSE = 13828$, $p = 0.03$. This result was in line with the claim that luminance is processed more easily (is more salient) than hue. The results confirmed also subjects' reports ranking the black and white stimuli as easier than the red/green stimuli.

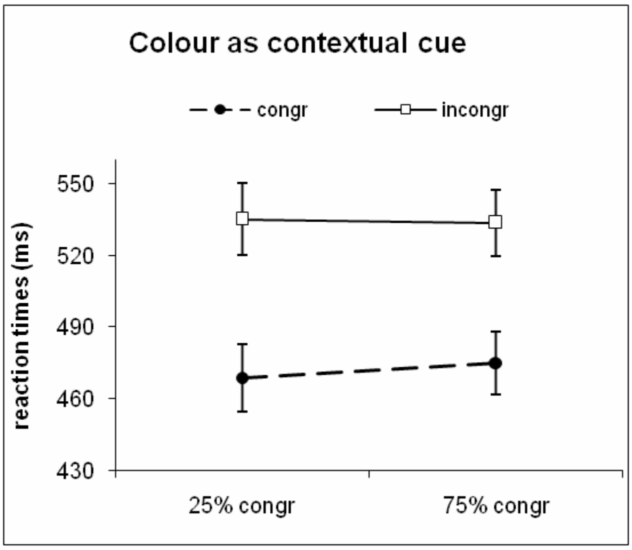
The results of both sessions analyzed together revealed significantly faster responses on congruent (463 ms) than on incongruent trials (527 ms):

$F(1, 20) = 299.4$, $MSE = 199149$, $p < 0.001$. Importantly, the flanker effect wasn't significantly modulated by ratio, $F(1, 20) < 1$. The Session x Ratio x Congruency interaction was only marginally significant: $F(1, 20) = 3{,}5$ $MSE = 585$, $p = 0.08$. There were no other significant main effects or interactions.

Colour session results

As the colour session was more or less precise replication of Vietze and Wendt's (2009) experimental layout, data from the colour session are described first.

Figure 3. Results of Experiment 2, Colour session. Mean reaction times for congruent trials (dashed line, the circle black markers; congr) and on incongruent trials (solid line, the square white markers; incongr) as a function of proportion congruent signalled by stimulus colour. congr = congruent; incongr = incongruent; 25% congr = 25% congruent trials and 75% incongruent trials; 75% congr = 75% congruent and 25% congruent trials.



Responses were faster on congruent (472 ms) than on incongruent trials (535 ms) $F(1, 22) = 254.7$, $MSE = 368$, $p < 0.001$ (Figure 3). In contrast to Vietze and Wendt's (2009) results, however, the flanker effect wasn't significantly modulated by ratio, $F(1, 22) = 2$, $MSE = 175$, $p = 0.2$; and was numerically even a little larger for the 25% ratio than 75% ratio (66 ms vs. 59 ms).

Similarly to the reaction times' pattern of results, there was significant main effect of Congruency in error rates, with more frequent errors for incongruent than congruent trials: 4.8% vs. 1.1%, $F(1, 22) = 29.5$, $MSE = 0.001$, $p < 0.001$. The flanker effect size was not modulated by ratio (3.3% vs. 4.1% for 25% ratio vs. 75% ratio, respectively).

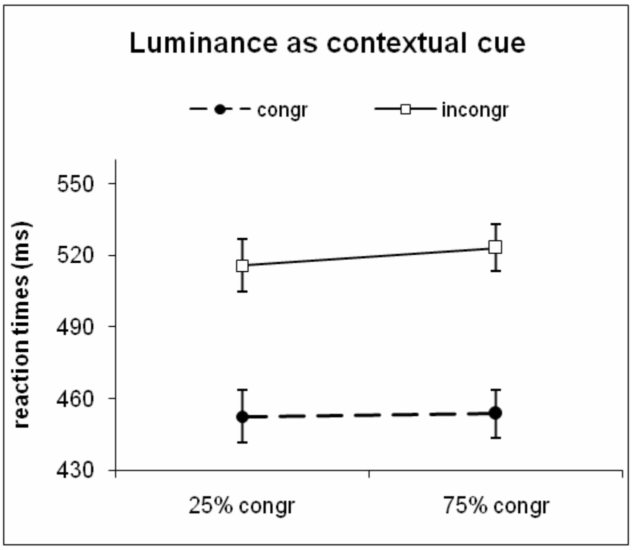
Comparably to Experiment 1, in reaction times' results a between subject factor (i.e. Colour–ratio assignment) interacted with Ratio: $F(1, 22) = 17.7$, $p < 0.001$. The between subject factor specify the colour (red vs. green) and the ratio (25% vs. 75%) assignment. According to this factor, we can divide all participants into two subgroups: first one, where red colour of stimuli was associated with 25% ratio (mainly incongruent arrays), while green colour of stimuli with 75% ratio (mainly congruent trials) and second subgroup, where red stimuli were mainly congruent and green mainly incongruent. In both subgroups reaction times were faster to red arrows than to green ones. According to participant's reports, the red arrows were higher discernible, and this is the most possible reason for this difference. The stimulus' colour was stronger predictor of reaction times than the ratio, thus for one group reaction times were shorter for 25% ratio (red stimuli), while for another group shorter reaction times were registered for 75% ratio (red stimuli).

Moreover, the three-way interaction Colour-ratio assignment x Ratio x Congruency was significant: $F(1, 22) = 7.3$, $p = 0.01$. This result allows evaluation of the Ratio x Congruency interaction separately for both subgroups. The flanker effects for the 25% ratio and the 75% ratio were 66 ms vs. 43 ms for the group where red was associated with the 25% ratio (Ratio x Congruency: $F(1, 11) = 8.2$, $MSE = 182$, $p = 0.02$) and 67 ms vs. 74 ms for the other group (here Ratio x Congruency interaction was insignificant: $F(1, 11) < 1$). Note that for the group where red was associated with 25% ratio the pattern of results was the reverse of that shown by Vietze and Wendt (2009).

Luminance session results

In the luminance session, two different ratios were associated with black or white stimuli, rather than with red or green arrows, as in the colour session. Similar to the colour session, a highly significant main effect of Congruency was seen, with faster responses for congruent than incongruent trials observed: 453 ms vs. 519 ms; $F(1, 22) = 162.8$, $MSE = 649$, $p < 0.001$.

Figure 4. Results of Experiment 2, Luminance session. Mean reaction times for congruent trials (dashed line, the circle black markers; congr) and on incongruent trials (solid line, the square white markers; incongr) as a function of proportion congruent signalled by stimulus luminance (black vs. white). congr = congruent; incongr = incongruent; 25% congr = 25% congruent trials and 75% incongruent trials; 75% congr = 75% congruent and 25% congruent trials.



In contrast to the colour session, the flanker effect was slightly smaller for the 25% congruent context than for the 75% congruent context: 63 ms vs. 69 ms. Nevertheless, this effect was not significant: $F(1, 22) = 1.7$, $MSE = 143$, $p = 0.2$.

Error rate analysis revealed significantly more frequent errors for incongruent than congruent trials: 0.6% vs. 4.7%; $F(1, 22) = 20.8$, $MSE = 0.002$, $p < 0.001$. The flanker effect was not modulated by ratio (4.2% vs. 3.9% for 25% ratio and 75% ratio, respectively).

As for the colour session, reaction times' results showed a between subject factor (i.e. 'Black&white–ratio assignment') interaction with Ratio: $F(1, 22) = 13$, $MSE = 188$, $p = 0.002$. This can be interpreted in a similar manner as the colour session effects. Participants were faster when responding to white rather than black stimuli, resulting in opposite patterns in the ratio subgroups. For one subgroup responses were faster for the 25% ratio (white stimuli), while the second subgroup showed shorter reaction times for the 75% ratio (white stimuli). Note that assignment of ratio to respectively colour and luminance was fully counterbalanced, thus half of participants confronted with for instance 'red – 25% ratio' assignment, were in the luminance session subgroup 'white – 25% ratio', while the other half were assigned to 'black – 25% ratio'. Thus, it was not the case that one half of participants were much faster than another, whatever condition was presented.

Discussion

The size of the flanker effect in Experiment 2 was not modulated by ratio (25% vs. 75%) distinguished by stimuli hue (red vs. green) or by luminance (black vs. white). Moreover, for the colour session, the flanker effect was slightly larger for the 25% ratio than the 75% ratio, although this was not significant. Thus, our study demonstrates the ineffectiveness of colour and luminance as contextual cues in the flanker task. Since neither hue nor luminance were crucial for the flanker task, this result can be easily accommodated to the claim that only dimensions crucial for the task can be effective cues for the different ratios within the block.

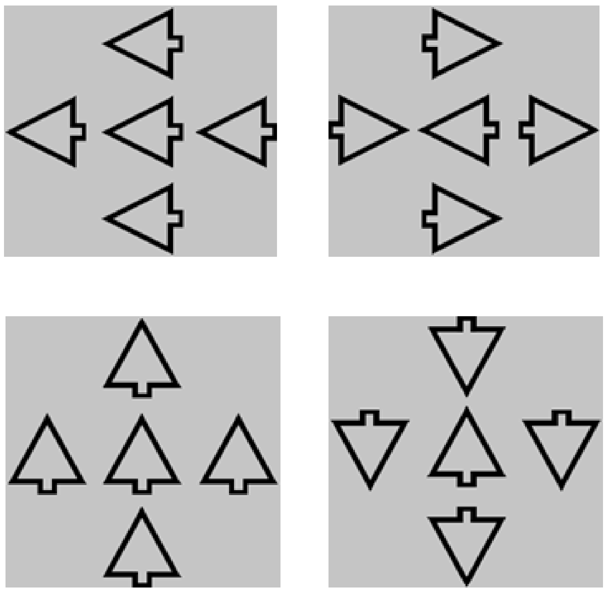
According to the relative saliency hypothesis we expected a stronger CSPC effect for the luminance session than for the colour session. Inspection of the flanker effect size obtained for both ratios revealed a weak CSPC effect in the luminance session, i.e. a slightly reduced flanker effect for 25% congruent and enhanced for 75% congruent, while the reverse pattern occurred in the colour session. Importantly, the flanker effect modulation by ratio was not significant in both parts. Though a trend in results consistent with the relative saliency hypothesis was observed, the three-way interaction Session x Ratio x Congruency was not significant. Therefore, these findings do not corroborate a role of relative saliency in cuing effects in the flanker task.

To sum up, Experiment 2 confirmed the task-relevancy role in predicting contextual cue effectiveness and questioned the role of relative saliency.

EXPERIMENT 3: ARROW DIRECTION AS CONTEXTUAL CUE

It might be assessed that task-relevancy of the feature used as a contextual cue in Experiment 1-3 has been enhanced. The dimension introduced as the contextual cue in Experiment 3 was highly relevant to the arrow flanker task. Since the participants had to determine the direction the arrow pointed, the most relevant information for such a task seems to be the identity of the target. And the very direction pointed by the arrows was the contextual cue in Experiment 3. The target arrow could point in one of four possible directions: left, right, up or down (Figure 5). Arrows pointing left or right were assigned to the 25% ratio, while arrows pointing up and down were associated with the 75% ratio for half of the subjects. The arrangement was the reverse for the other half of the subjects.

Figure 5. Stimulus displays used in Experiment 3. Top row: examples of left pointing target-arrow; bottom row: examples of up pointing target-arrow. The left column: examples of congruent trials, the right column: examples of incongruent trials.



According to the task-relevance hypothesis as well as the relative saliency hypothesis, a clear CSPC effect would be expected here. The manipulation implemented here resembles the experimental layout used by Jacoby, Lindsay and Hessels (2003) in the Stroop task. They assigned particular ratios to the two sets of three colour words each. In their study one set contained WHITE, YELLOW and RED, while another set, GREEN, BLUE and BLACK. We implement such layout in the flanker task. Colours in Jacoby et al. study (2003) can be grouped naturally as brighter and dimmer. In the present study, two sets of stimuli were created in an even more intuitively way: the right-pointing arrow was in one set with the left-pointing arrow, while the up-pointing arrow was with the down-pointing arrow in common set. Separation between these sets was additionally enhanced by the fact that arrows coming from two different sets were never presented together.

Method

Participants

There were 22 participants in Experiment 3 (3 males), the age ranged between 19 and 38 (mean age: 25.2); 20 of them were right-handed (self reported). One further persons took part in Experiment 3, but his data were discarded, due to the percent correct rate lower than 75% in at least one condition.

Stimuli, procedure and apparatus

The arrows which served as targets and flankers were slightly different than those used in Experiment 1-2 (Figure 5). Instead of uniformly coloured arrows without visible edges, stimuli drawn black on grey and filled with grey inside were used (designed in Power Point rather than in Presentation). The single arrow could be fitted to a 1 cm x 1 cm square making a visual angle of 1 x 1 degree at the viewing distance of ca. 50 cm. The target arrow was presented centrally and surrounded by four arrows, arranged similarly to Experiment 1-2. The target arrow could point to the one of four possible directions: left, right, up or down.

Participants responded by pressing one of relevant arrows keys of standard keyboard (up-arrow key for the target pointing up, left-arrow key for the target pointing left etc.) with one finger of their dominant hand.

The target arrow pointing to the left/right was surrounded either by flankers pointing to the left/right (on congruent trials) or by flankers pointing to the right/left (on incongruent trials). Similarly, the target arrow pointing to down/up was surrounded by flanking arrows pointing to the down/up (on congruent trials) or by flanking arrows pointing to the up/down (on incongruent trials). Left or right pointing arrows were never presented with up or down pointing arrows within one trial. There were eight possible configurations (four possible directions pointed by the target arrow x congruency), and in a given trials there was an equal probability of each configuration occurring.

Left and right pointing arrows were associated with the 25% ratio, while up and down pointing arrows with the context 75% ratio for half of the subjects and the reverse for the other half of the subjects. The ratio across experiment was overall 50% congruent.

Each trial started with blank screen presented for about 200 ms, then a fixation point (small black square) in the centre of the screen appeared for 616 ms. Next, target and flankers were presented against uniformly grey background for about 316 ms. The participant's response started the next trial.

There were 960 trials in the experiment. Half of them contained a left or right pointing target arrow and were associated with 75% congruent (for half of participants). Then there were 360 congruent trials and 120 incongruent (50% of each group were trials pointing to the left). Consequently, up-down pointing arrows associated with the 25% ratio contained 120 congruent trials and 360 incongruent trials. Note that participants were not informed about the fact that direction pointed by arrow was a contextual cue.

Participants were tested individually in a dark room with a standard PC computer. First the demo version, identical to the main part of the experiment, but shorter, was presented. Instructions to press one of four arrow keys as fast and as accurately as possible according to the target arrow direction were given. The first session, lasting about 10 minutes, started after the short training period. A second, identical session was performed after a short break; the whole experiment length was about 25 minutes.

Responses were given by pressing arrow keys on a standard keyboard with one finger of the dominant hand. The stimuli were presented on a 19-inch monitor with a 75 Hz refresh rate, situated about 50 cm from participant face. Presentation software (v. 9.1, Neurobehavioral System Inc.) controlled stimuli displays and collected responses.

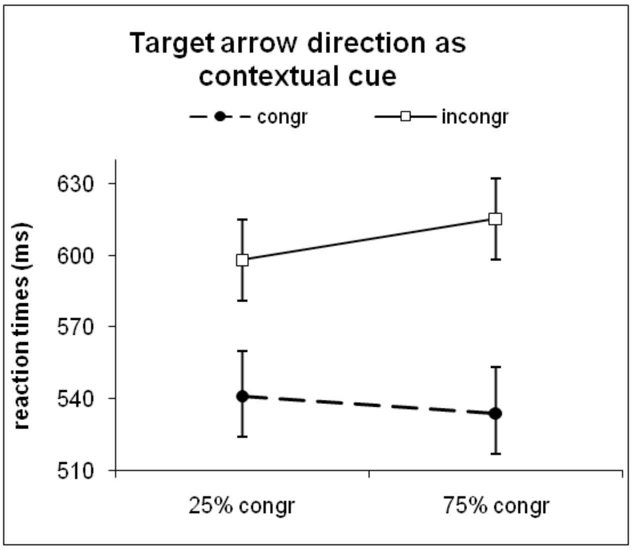
Mean reaction times (RT) were calculated with exclusion of incorrect responses and reaction times which were shorter than 200 ms and longer than 1700 ms. RTs outside this response window were considered as errors.

The statistical analysis method and variables were the same as used in Experiment 1.

Results

Responses were faster on congruent (538 ms) than incongruent trials (607 ms): $F(1, 20) = 103.4$, $MSE = 1018$, $p < 0.001$. Importantly, the flanker effect was smaller for the 25% ratio than for the 75% congruent context (57 ms vs. 81 ms); the Ratio x Congruency interaction was significant; $F(1, 20) = 13.5$, $MSE = 237$, $p = 0.001$ (Figure 6).

Figure 6. Results of Experiment 3. Mean reaction times for congruent trials (dashed line, the circle black markers; congr) and on incongruent trials (solid line, the square white markers; incongr) as a function of proportion congruent signalled by the arrow direction (left-right vs. up-down). congr = congruent; incongr = incongruent; 25% congr = 25% congruent trials and 75% incongruent trials; 75% congr = 75% congruent and 25% congruent trials.



Similarly, error rates were higher for incongruent than congruent trials: 4.8% vs. 2%, $F(1, 20) = 22.5$, $MSE = 0.001$, $p < 0.001$. Moreover, there was also difference in the flanker effect size between ratios: 1.7% vs. 4% for 25% ratio and 75% ratio, respectively; $F(1, 20) = 7.7$, $MSE < 0.001$, $p = 0.01$.

Although a between-subjects factor, i.e. the assignment of a certain ratio to arrows' directions, was not significant for both reaction times and error rates, it interacted significantly with ratio for the error rates results: $F(1, 20) = 13.2$, $p = 0.002$. For both subgroups of participants errors were more frequent for the 75% congruent ratio than for the 25% congruent ratio, but this difference was larger in the subgroup with assignment '25% ratio - left-right pointing'. For this subgroup there were 2.7% errors for 25% congruent and 4.6% for 75% congruent, while for the other subgroup the percent errors were 2.7% vs. 3.5% for each ratio. The assignment 'pointing direction – ratio' as the between-subjects factor, produced a significant three-way interaction for Assignment x Ratio x Congruency for error rates results: $F(1, 20) = 15.1$, $p = 0.001$. For both subgroups, which differed in the assignment type, the flanker effect was modulated by ratio: larger for 75% congruent and smaller for 25% congruent. It was, however, much clearer for those participants who experienced the 25% ratio when responding to the left-right pointing arrows. For them the flanker effect was 0.9% for 25% congruent and 6.3% for 75% congruent. The other subgroup had a 1.7% flanker effect in errors for the 25% ratio and 2.4% flanker effect in error rate for the 75% ratio.

Discussion

The arrow direction, presumably the most relevant feature in the arrow-flanker task, served as a contextual cue in Experiment 3. In line with the claim that task-relevancy is crucial in predicting the effectiveness of a given feature as the contextual cue, a clear CSPC effect was obtained. The flanker effect was different for left-right vs. up-down pointing arrows, always larger for the 75% ratio and smaller for the 25% ratio. This pattern of results was present in reaction times as well as in error rates.

Note also, that the CSPC effect was obtained here in spite of the fact that participants were not informed about the arrow direction – ratio contingency.

GENERAL DISCUSSION

Flexibility of human cognitive system has been demonstrated repeatedly. One example of this is the finding that the noise effect is enhanced when congruent trials prevail in a block and reduced when incongruent trials prevail, observed in numerous experiments (for instance: Gratton et al., 1992; Logan, 1980; Toth et al., 1995; Kane & Engle, 2003; Funes et al., 2010). Recently the knowledge about this flexibility was further broadened. Presenting mostly congruent trials, say, above the fixation point, results in an enhanced congruency effect, while a reduced congruency effect was registered for the bottom position where trials were mainly incongruent (Crump et al., 2006; Crump et al., 2008; Crump & Milliken, 2009; Żurawska vel Grajewska et al., 2011). This on the fly modulation was termed a context-specific congruent proportion effect (Crump et al., 2006). The feature which distinguish the context of high and low congruent ratios was called a contextual cue (Crump et al., 2006). In the example described above, the spatial location (above/below) was such a contextual cue.

The CSPC effect has been demonstrated not only for spatial location as the contextual cue (Corballis & Gratton, 2003; Wendt et al., 2008; Crump & Milliken, 2009; Crump et al., 2006; Crump et al., 2008; Żurawska vel Grajewska et al., 2011), but also colour (Jacoby et al., 2003; Vietze & Wendt, 2009; Bugg et al., 2008) and even font type (Bugg et al., 2008). There have been, however, some reports of the ineffectiveness of such manipulations. Stimulus shape in the Stroop task failed in the role of contextual cue (Crump et al., 2006), and colour in one type of the flanker task was effective only after specific training (Lehle & Hübner, 2008). The spatial position of a to-be-read word did not exert a CSPC effect (although a colour patch which primed the word, delayed a response when it was incongruent; Crump et al., 2008, Exp. 3b). Thus, it is still debatable what boundary conditions are for the contextual cue to be effective.

It was hypothesized that effectiveness of a given feature in the contextual cue role is specific for the task. It may be critical whether a given dimension is crucial for the task, like colour for the Stroop task and spatial position for the flanker task (Lehle & Hübner, 2008). According to this 'task-relevancy claim', only task-relevant aspects of stimulation can cue the context. Some findings confirmed this presumption (Jacoby et al., 2003; Corballis & Gratton, 2003; Lehle & Hübner, 2008; Crump et al., 2006; Crump et al., 2008; Żurawska vel Grajewska et al., 2011; Wendt et al., 2008), while other demonstrated effectiveness of cues irrelevant for the task: the spatial location and font type in the Stroop task (Crump et al., 2006; Crump et al., 2008; Crump & Milliken, 2009; Bugg et al., 2008), and colour in the classic flanker task (Vietze & Wendt, 2009). Crump and colleagues assumed that location, although irrelevant for colour naming tasks, cued context efficiently because of its special status in visual scene processing (Crump et al., 2008), what can be also interpreted as the effect of high saliency of the spatial location.

The aim of the present paper was to test the task-relevance claim and the relative saliency role assumption. To achieve this goal the contextual cue relevancy in the flanker task was manipulated from fully irrelevant to highly task relevant in three experiments. Table 1 summarizes the experimental manipulations in each experiment and the results obtained. Additionally the relative saliency was also manipulated in some of the experiments.

Results of all experiments in the present study were consistent and all supported the assumption that critical factor for predicting a given contextual cue effectiveness was its relevance for the flanker task. The CSPC effect was absent in experiments employing task-irrelevant contextual cues and present in experiment where the contextual cue was task-relevant. Additionally, to check the impact of

Table 1. Contextual cues used in each experiment, level of its task-relevance and presence of the CSPC effect.

	Experiment 1	Experiment 2		Experiment 3
Contextual cue	colour of background	colour of arrows	luminance of arrows	direction of target arrow
Task-relevancy	very low	low	low	high
CSPC effect	no	no	no	yes

task-relevancy, which was gradually enhanced from the first to the last experiment in the present paper, results of all three experiments were submitted to repeated-measures ANOVA. Such a direct comparison was done for the first time in the present study and offered a good test for the proposed hypothesis, as the experimental layout in each experiment was similar. A between-subject variable was 'Experiment', while within-subject factors were Ratio and Congruency, present in all experiments. These analysis revealed a significant three-way interactions for Experiment x Ratio x Congruency: $F(2, 65) = 6.5$, $p = 0.003$ when the luminance session from Experiment 2 was compared with Experiment 1 and 3 and $F(2, 65) = 8.5$, $p = 0.001$ when the colour session was included into comparison. (Only one session from Experiment 2 was included each time to keep the data format constant). The CSPC effect was indeed different across experiments. The role of relevancy was confirmed.

Last but not least conclusions can be drawn from the present data in reference to the role of awareness in the CSPC effect. Since we obtained the CSPC effect in experiment when participants were not informed about the ratio - contextual cue form contingency and no effect was seen in the two experiments when such information was provided, prior knowledge about expected contingency can be excluded as critical reason for presence or absence of the effect. This is in line with Crumps and colleagues' conclusions (Crump et. al, 2008), who addressed directly this issue and found an unaffected pattern of results in spite of informing participants about contingency in an extensive way. Our study provided demonstration of the CSPC effect, when participants weren't informed in advanced about the contextual cue, which is rare in the CSPC procedure.

In summary, all results observed in the present paper support the claim that task-relevance is a crucial boundary condition when the determining whether a contextual cue will be effective. The more relevant a feature, the better the chances that it will efficiently provide a context cue. Furthermore, our results provide evidence against the relative saliency of contextual cues having an important role in evoking the CSPC effect. Moreover, prior knowledge about cue meaning is neither a necessary nor a sufficient condition for the CSPC effect to be observed. Finally, this is also first report examining possibility of the CSPC effect being evoked by the luminance of stimuli (none was seen) and the background colour (which also was not effective).

REFERENCE

Bartholow, B. D., Pearson, M., Sher, K. J., Wieman, L. C., Fabiani, M. & Gratton, G. (2003). Effects of alcohol consumption and alcohol susceptibility on cognition: a psychophysiological examination. *Biological Psychology, 64*, 167-190.

Bélanger, S., Belleville, S. & Gauthier, S. (2010). Inhibition impairments in Alzheimer's disease, mild cognitive impairment and healthy aging: effect of congruency proportion in a Stroop task. *Neuropsychologia, 48*, 518-590.

Botvinick, M. M., Nystrom, L. E., Fissell, K., Carter, C. S. & Cohen J.D. (1999). Conflict monitoring versus selection-for-action in anterior cingulate cortex. *Nature, 402*, 179-181.

Bugg, J. M., Jacoby, L. L. & Toth, J. P. (2008). Multiple levels of control in the Stroop task. *Memory and Cognition, 36,* 1484-1494.

Buswell, G.T. (1935). *How People Look at Pictures*. Chicago: Univ. Chicago Press

Carter, C. S., MacDonald, A. M., Botvinick, M. M., Ross, L. L., Stegner, V. A. & Noll, D. (2000). Parsing executive processes: strategic vs. evaluative functions of the anterior cingulate cortex. *Proceedings of National Academy of Sciences U.S.A., 97*, 1944-1948.

Casey, B. J., Thomas, K. M., Welsh, T. F., Badgaiyan, R. D., Eccard, C. H., Jennings, J. R. & Crone, E. A. (2000). Dissociation of response conflict, attentional selection, and expectancy with functional magnetic resonance imaging. *Proceedings of National Academy of Sciences U.S.A., 97*, 8728-8733.

Corballis, P. M. & Gratton, G. (2003). Independent control of processing strategies for different locations in the visual field. *Biological Psychology, 64*, 191-209.

Crump, M. J. C., Gong, Z. & Milliken, B. (2006). The context-specific proportion congruent Stroop effect: location as a contextual cue. *Psychonomic Bulletin & Review, 13*, 316-321.

Crump, M. J. C. & Milliken, B. (2009). The flexibility of context-specific control: evidence for context-driven generalization of item-specific control settings. *Quarterly Journal of Experimental Psychology, 62*, 1523-1532.

Crump, M. J. C., Vaquerro, J. M. & Milliken, B. (2008). Context-specific learning and control: the roles of awareness, task relevance, and relative salience. *Consciousness and Cognition, 17*, 22-36.

Eriksen, B. A. & Eriksen, C. W. (1974). Effects of noise letters upon the identification of a target letter in a nonsearch task. *Perception & Psychophysics, 14,* 155-160.

Fernandez-Duque, D. & Knight, M. B. (2008). Cognitive control: dynamic, sustained, and voluntary influences. *Journal of Experimental Psychology: Human Perception and Performance, 34*, 340-355.

Folk, C. L., Leber, A. B. & Egeth, H. E. (2002). Made you blink! Contingent attentional capture produces a spatial blink. *Perception & Psychophysics, 65,* 741-753.

Folk, C. L., Remington, R. W. & Johnston, J. C. (1992). Involuntary covert orienting is contingent on attentional control settings. *Journal of Experimental Psychology: Human Perception and Performance, 18,* 1030-1044.

Funes, M. J., Lupiánez, J. & Humphreys, G. (2010). Sustained vs. transient cognitive control: evidence of a behavioral dissociation. *Cognition, 114*, 338-347.

Gratton, E., Coles, M. G. H. & Donchin, E. (1992). Optimizing of the use of information: Strategic control of activation of responses. *Journal of Experimental Psychology: General, 121*, 480-506.

Hantsch, A., Jescheniak, J. D. & Schriefers, H. (2009). Distractor modality can turn semantic interference into semantic facilitation in the picture-word interference task: implications for theories of lexical access in speech production. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 35*, 1443-1453.

Hommel, B. (1994). Spontaneous decay of response-code activation. *Psychological Research, 56,* 261-268.

Jacoby, L. L., Lindsay, D. S. & Hessels, S. (2003). Item-specific control of automatic processes: stroop process dissociations. *Psychonomic Bulletin & Review, 10*, 638-644.

Johnson, D. N. & Yantis, S. (1995). Allocating visual attention: tests of a two-process model. *Journal of Experimental Psychology: Human Perception and Performance, 21*, 1376-1390.

Kane, M. J. & Engle, R. W. (2003). Working-memory capacity and the control of attention: The contributions of goal neglect, response competition, and task set to Stroop interference. *Journal of Experimental Psychology: General, 132*, 47-70.

Lavie, N., Hirst, A., de Fockert, J. W. & Viding, E. (2004). Load theory of selective attention and cognitive control. *Journal of Experimental Psychology: General, 133*, 339-354.

Lehle, C. & Hübner, R. (2008). On-the-fly adaptation of selectivity in the flanker task. *Psychonomic Bulletin & Review, 15*, 814-818.

Logan, G. D. (1980). Attention and automaticity in Stroop and priming tasks: theory and data. *Cognitive Psychology, 12*, 523-553.

Logan, G. D. & Zbrodoff, N. J. (1979). When it helps to be misled: Facilitative effects of increasing the frequency of conflicting stimuli in a Stroop-like task. *Memory & Cognition, 7*, 166-174.

Marr, D. (1982). *Vision: A Computational Investigation into the Human Representation and Processing of Visual Information.* New York: Freeman.

Mattler, U. (2006). Distance and ratio effects in the flanker task are due to different mechanisms. *The Quarterly Journal of Experimental Psychology, 59,* 1745-1763.

Merikle, P. M. & Joordens, S. (1997). Parallels between perception without attention and perception without awareness. *Consciousness and Cognition, 6,* 219-236.

Navon, D. & Kasten, R. (2008). Incidental learning of secondary attentional cueing. *Acta Psychologica, 127,* 459-475.

Simon, J. R. (1990). The effects of an irrelevant directional cue on human information processing. In R. W. Proctor & T. G. Reeve (Eds.), *Stimulus-response compatibility* (pp. 31-86). Elsevier Science Publishers.

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology: General, 18,* 662.

Stürmer, B., Leuthold, H., Soetens, E., Schröter, H. & Sommer, W. (2002). Control over location-based response activation in the Simon task: behavioral and electrophysiological evidence. *Journal of Experimental Psychology: Human Perception and Performance, 28,* 1345-1363.

Theeuwes, J. & Kooi, F. L. (1994). Parallel search for a conjunction of contrast polarity and shape. *Vision Research, 34*, 3013-3016.

Toth, J. P., Levine, B., Stuss, D. T. & Oh, A. (1995). Dissociation of processes underlying spatial S-R compatibility: Evidence for the independent influence of what and where. C*onsciousness and Cognition, 4,* 483-501.

Vietze, I. & Wendt, M. (2009). Context specifity of conflict frequency-dependent control. *The Quarterly Journal of Experimental Psychology, 62,* 1391-1400.

Wendt, M., Kluwe, R. H. & Vietze, I. (2008). Location-specific versus hemisphere-specific adaptation of processing selectivity. *Psychonomic Bulletin & Review, 15*, 135-140.

Żurawska vel Grajewska, B., Sim, E.-J., Hönig, K., Herrnberger, B. & Kiefer, M. (2011). Mechanisms underlying flexible adaptation of cognitive control: Behavioral and neuroimaging evidence in a flanker task. *Brain Research, 1421*, 52-65

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