Consciousness and Cognition 125 (2024) 103773

Contents lists available at ScienceDirect

Consciousness and Cognition

journal homepage: www.elsevier.com/locate/yccog

Stretching the limits of automated symbolic orienting

Mario Dalmaso [a,*], Giovanni Galfano [a], Luigi Castelli [a]

[a] *Department of Developmental and Social Psychology, University of Padova, Italy*

A R T I C L E I N F O

Keywords:
Automated symbolic orienting
Attention
Spatial cueing
Arrows

A B S T R A C T

Arrows trigger reflexive shifts of attention and instantiate the prototypical example of automated symbolic orienting. We conducted four experiments to further test the boundary conditions of this phenomenon. Participants discriminated a peripheral target while spatially uninformative arrows, pointing leftwards or rightwards, appeared at fixation. In all experiments, arrow direction could either randomly vary (intermixed condition) or be kept constant within a block of trials (blocked condition). Moreover, in Experiments 3 and 4, a direction word presented at the beginning of the trial informed participants about the target location with 100% certainty. Overall, the results highlighted a significant arrow-driven orienting effect in both the blocked and the intermixed conditions. The present findings support the notion that automated symbolic orienting is resistant to suppression in that it endures even when the context should stress the uninformative nature of the arrows while also creating ideal conditions to boost participants' tendency to ignore them.

1. Introduction

Arrows are ubiquitous communicative symbols in our society. For instance, drivers worldwide know that arrows indicate which direction to take at a crossroads. In human–computer interfaces, arrows are largely used as they allow us to easily navigate among different pages and contents (e.g., Burigat et al., 2008). Hence, their use in different domains is grounded on the unambiguous meaning they convey.

Arrows have been investigated thoroughly in cognitive psychology as spatial cues for attention. Some of the first evidence addressing whether humans are capable of covertly orienting attention in space relied on arrows presented at fixation signalling the most likely location for a subsequent target stimulus (e.g., Posner et al., 1980). For long, it has been thought that, unlike other types of signals (such as abrupt onsets; Jonides, 1981), centrally displayed arrows could push one's attention away from fixation only provided they conveyed task-relevant information about the appearance of the subsequent target (i.e., providing the observer with information that could reliably predict its future location). However, Eimer (1997) provided evidence that significant attention cueing effects (i.e., better performance to spatially congruent trials than to spatially incongruent trials) could be obtained both when arrows were highly predictive of the location of subsequent targets and when the target was equally likely to appear at the cued and uncued location. This result was later replicated by Hommel et al. (2001), thus further demonstrating that symbolic signals can cue attention regardless of whether they provide reliable information or not (also see Ristic et al., 2002; Tipples, 2002).

A more recent study aimed to clarify the nature of this phenomenon was conducted by Ristic and Kingstone (2012), who applied the additive factor method (e.g., Sternberg, 2001). Using a simultaneous double-cueing procedure, they showed that a central

* Corresponding author at: Department of Developmental and Social Psychology, University of Padova, Via Venezia 8, 35131, Padova, Italy.
E-mail address: mario.dalmaso@unipd.it (M. Dalmaso).

https://doi.org/10.1016/j.concog.2024.103773
Received 25 July 2024; Received in revised form 15 October 2024; Accepted 18 October 2024

uninformative arrow produced orienting of attention effects additive with respect to those elicited by either uninformative peripheral abrupt onsets or informative central digit numbers (predicting the target location on the majority of the trials). This pattern was interpreted as reflecting a novel modality of attentional orienting, independent of classic exogenous and endogenous control (also see Hayward & Ristic, 2016). Ristic and Kingstone (2012) argued that this phenomenon could represent an instance of automated symbolic orienting, in that it shared important features with classic exogenous orienting induced by abrupt onsets but was likely reflecting a reflexive, involuntarily-triggered, mechanism resulting from massive previous practice in daily life. One way to address whether orienting driven by arrows genuinely underlies extensive practice is to test whether such an effect differs between children and adults. In this regard, Ristic and Kingstone (2009; also see Ristic et al., 2002) demonstrated that preschool children exhibit symbolic cueing of attention driven by uninformative arrows and that this effect seems to be similar in magnitude as compared to that displayed by adults

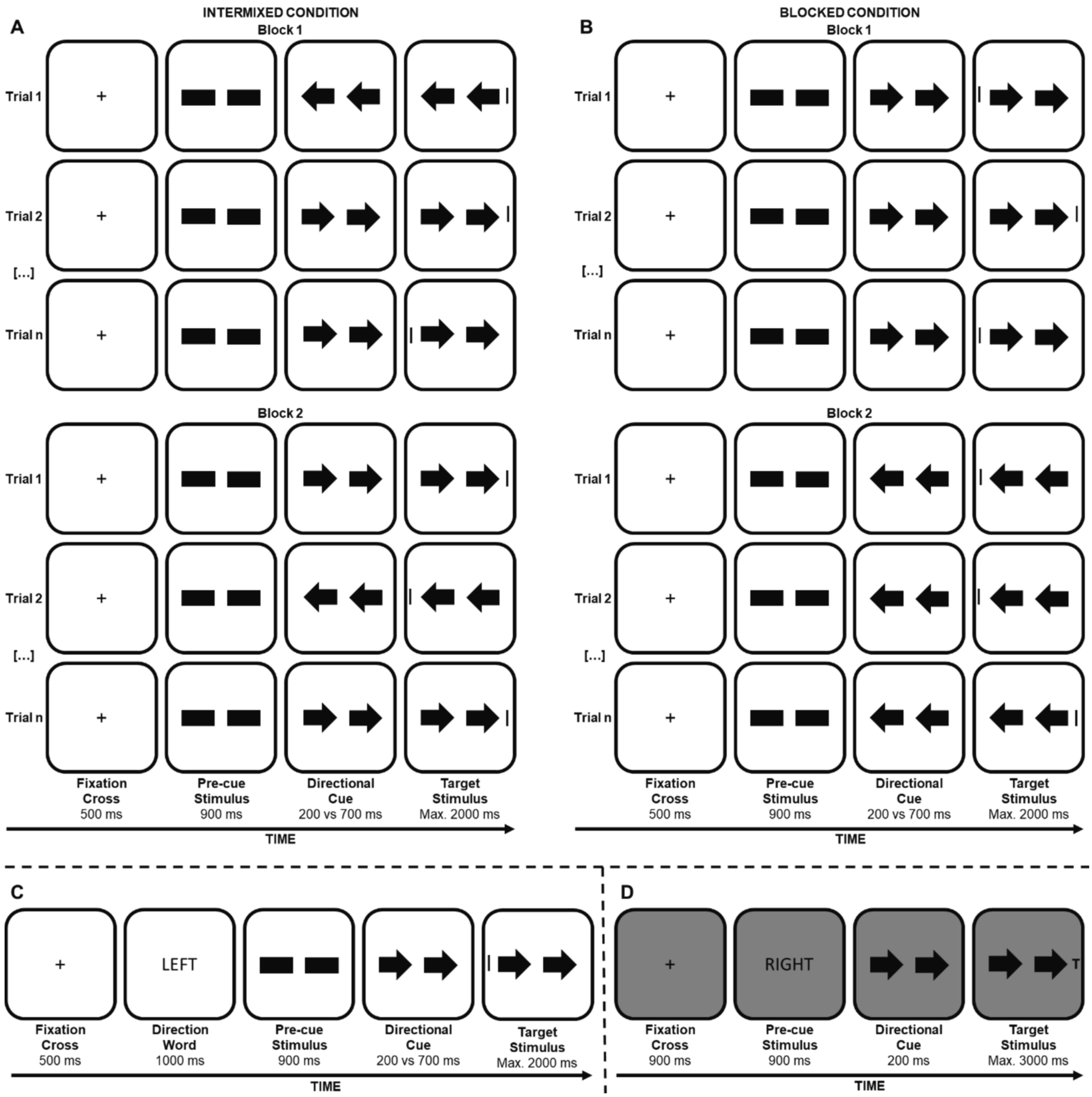

Fig. 1. Panel A depicts the 'intermixed' condition used in Experiment 1, in which arrow stimuli pointed leftwards or rightwards with the same probability. Panel B depicts the 'blocked' condition used in Experiment 1, in which arrow stimuli consistently pointed leftwards or rightwards within two separate blocks. Panel C and D depict trials used in Experiment 3 and 4, respectively, in which a direction word, always predictive of the location of the upcoming target, was presented before the arrows. Experiment 2 was similar to Experiment 4 (Panel D), with the exception that no direction word was present.

(undergraduate students). Later, however, tentative evidence supporting the idea that arrow-driven orienting may reflect overlearning the meaning of useful everyday symbols has been reported comparing children younger than 4 years and children older than 5 years (Jakobsen et al., 2013). Interestingly, only children older than 5 years appeared to be able to orient their attention as a function of the conceptual meaning of arrows.

The present study was aimed to address the automaticity related to symbolic orienting among adults (i.e., when the conceptual meaning of arrows is already well established). This issue has been the target of several previous studies focused on different facets of automaticity (e.g., Carraro et al., 2015; Cole & Kuhn, 2010; Dalmaso, Castelli et al., 2023a; Gayet et al., 2014; Guzzon et al., 2010; Kuhn & Kingstone, 2009; Ristic et al., 2002; Schmitz et al., 2024). In this regard, using a dual-task methodology, Yokohama et al. (2022) found that a significant arrow-driven orienting effect could be observed even when a resource-consuming spatial working memory task was concurrently performed. Other studies were concerned with the manipulation of expectancies. Gibson and Bryant (2005) used a spatial cueing procedure combined with a visual search task with a fixed 8-item display. Importantly, cues were predictive of the target location only in 1/8 of the total trials. This manipulation should have resulted in making arrows less likely to be voluntarily processed as compared to the classic paradigm with only two possible target locations (e.g., Tipples, 2002), since the informational value about the possible target location conveyed by the arrow dropped from 50 % to 12.5 %. The results unequivocally showed that, despite the arrow being potentially disruptive for the task at hand, the participants exhibited a better performance when the target appeared at the location indicated by the arrow as compared to spatially incongruent trials. Friesen et al. (2004) and Tipples (2008) have used a manipulation in which arrow cues were counterpredictive as concerns the target location (i.e., participants were informed that after seeing an arrow pointing leftwards, the target was much more likely to be presented on the right, and vice versa). Their results showed that, at least at short Stimulus Onset Asynchronies (SOAs), performance was better when targets appeared at the locations signalled by arrows, even if participants knew that these trials were rare. Further studies using manipulations aimed to avoid, or at least minimize, the occurrence of voluntary processing of the cue stimulus confirmed that automated symbolic orienting is apparently impervious to voluntary control (e.g., Dalmaso et al., 2020; Galfano et al., 2012).

The main goal of the present study was to further test the boundary conditions of automated symbolic orienting. In so doing, we aimed to defuse the informative value of arrow stimuli as much as possible, without manipulating expectancies, in order to reduce the likelihood of voluntary processing. To this end, we created a condition in which uninformative arrow cues always pointed in the same direction throughout a block of trials and compared this scenario with a classic setting in which cue direction varied unpredictably from trial to trial (also see Dalmaso et al., 2024). In the latter condition (intermixed condition), in line with the literature, we expected a regular arrow-driven orienting effect (e.g., Eimer, 1997; Ristic & Kingstone, 2012; Tipples, 2002). Most importantly, we reasoned that finding an unaltered symbolic cueing effect in the condition in which arrow direction was blocked (blocked condition) would be robust evidence for strong resistance to suppression.

2. Methods

2.1. Experiment 1

2.1.1. Participants

We tested eighty participants (*Mean age* = 22 years, *SE* = 0.23, 30 males). Sample size was determined a priori following the guidelines (Brysbaert & Stevens, 2018) for linear-mixed models (see the results section). Briefly, these guidelines indicate to collect at least a minimum of 1600 observations per experimental condition. According to our paradigm (see the next section) the minimum required number of participants was fifty. All participants were naïve as to the purpose of the experiment, were volunteers, and provided informed consent. The local Ethics Committee for Psychological Research approved the study, which was conducted in accordance with the Declaration of Helsinki.

2.1.2. Apparatus, stimuli, and procedure

The experiment was built with PsychoPy and run online with Pavlovia (Bridges et al., 2020). No smartphones or tablets were allowed. Symbolic cue stimuli consisted of two black arrows both pointing leftwards or rightwards (see Fig. 1). These stimuli were employed in a previous study (Dalmaso et al., 2021). The area occupied by each arrow was about 55 px width × 40 px height. The screen background was white.

Each trial started with a central black fixation cross (font: Arial; size: 0.1 normalised units) for 500 ms. After that, the two arrows first appeared for 900 ms without the heads (pre-cue stimulus), and then the two heads appeared pointing both leftwards or rightwards. After either 200 ms or 700 ms (SOA), a peripheral target stimulus appeared ± 0.8 normalised units either leftwards or rightwards with respect to the centre of the screen. The target was a black line oriented either horizontally or vertically (width: 40 px; height: 12 px). Participants were requested to look centrally for the whole duration of the trial, to ignore the arrows as they were not predictive of the target location, and to discriminate the orientation of the target by providing fast and accurate responses (time limit was set to 2000 ms). Responses were delivered through the keyboard by using the 'F' and the 'K' keys (the association between keys and the orientation of the line was counterbalanced across participants). Feedback was delivered when a missed or a wrong response occurred, namely the black words 'TOO SLOW' or 'NO' (font: Arial; size: 0.1 normalised units) appeared for 500 ms in the centre of the screen.

Four blocks were administered. In the so-called 'intermixed' condition, which included two consecutive blocks, the direction of the arrows was randomised within each block. In the so-called 'blocked' condition, the two arrows always pointed leftwards in one block, and rightwards in another block. The order of these conditions, as well as the direction of the arrows in the blocked condition, were counterbalanced across participants. All the other experimental conditions resulting from the manipulation of SOA and spatial congruency appeared in random order. Participants first completed a practice session of 12 trials, followed by the four experimental blocks of 64 trials each, totalling 256 experimental trials. The practice block varied depending on the specific experimental condition presented first. A break was conceded after each block.

2.1.3. Results

Data were analysed with R. First, we removed missing responses (0.22 % of trials) and wrong responses (4.80 % of trials; these latter responses were analysed separately). Second, we eliminated trials with a correct response whose latency was smaller than 150 ms or greater than 1500 ms (0.43 % of trials). Our design included congruency (2: congruent vs. incongruent), SOA (2: 200 vs. 700 ms) and condition (2: intermixed vs. blocked)[1] as within-participant factors.

The latencies of correctly-responded trials were analysed with a linear mixed-effect model (computed with the 'lme4′ package; Bates et al., 2015), which was selected by comparing (by using the 'MuMin' package; Bartoń, 2024) different models of increasing complexity. Standard effect sizes were calculated. The minimum number of observations per experimental condition was 2410 and therefore sufficient power was achieved. The best model included congruency, SOA, and condition, and their interactions as fixed effects, and the random effect was the intercept for participants and the by-participant random slope for the effect of condition. The main effect of congruency was significant, $F(1, 19196.3) = 58.311$, $p < 0.001$, $\eta_p^2 = 0.278$, as latencies were smaller on congruent ($M =$ 594 ms, $SE = 8.7$) than on incongruent ($M = 609$ ms, $SE = 8.7$) trials, as well as the main effect of SOA, $F(1, 19197.8) = 487.080$, $p <$ 0.001, $\eta_p^2 = 0.623$, as latencies were smaller at the 700-ms ($M = 580$ ms, $SE = 8.7$) than at the 200-ms SOA ($M = 623$ ms, $SE = 8.7$). This latter outcome likely reflected a foreperiod effect (e.g., Bertelson & Tisseyre, 1968). The congruency × SOA interaction was also significant, $F(1, 19196.1) = 6.551$, $p = 0.010$, $\eta_p^2 = 0.085$; the comparisons (computed with the 'lsmeans' package; Lenth, 2016) between congruent vs. incongruent trials conducted separately for each SOA were both significant ($ps < 0.001$), but the difference was greater at the 700-ms SOA (19 ms vs. 10 ms), consistent with previous reports addressing the time course of orienting effects elicited by uninformative central cues (e.g., Dalmaso et al., 2015; Ristic & Kingstone, 2009). No other significant results emerged ($ps > 0.31$; see also Table 1).

Errors were analysed by comparing mixed-effect logit models (computed with the 'lme4′ package; Bates et al., 2015). The best model was the null model, namely the one only including participant as random effect.

2.1.4. Discussion

The pattern of results that emerged in the present experiment showed a robust arrow-driven orienting effect with no hint of further modulation as a function of whether arrow direction was kept constant within each block (blocked condition) or varied unpredictably from trial to trial (intermixed condition). This, in turn, casts tentative evidence suggesting that the cueing effect exerted by uninformative arrows is hardly overridden by contextual manipulations.

In the next experiment, we aimed to test the robustness of these outcomes by introducing two main changes with respect to the experimental paradigm. First, we removed the pre-cue stimulus, in order to abolish any apparent motion phenomena which, in turn, might inflate attention cueing effects produced by central signals (e.g., McKay et al., 2021). Second, we switched to a task that did not require discrimination of spatial features of the target, thus minimizing the possibility that participants processed the spatial features of the arrows because they were contingent on their attentional control settings (e.g., Folk et al., 1992). We also decided to run the experiment in a more controlled lab-based setting.

2.2. Experiment 2

2.2.1. Participants

Sample size was determined a priori following the same guidelines (Brysbaert & Stevens, 2018) adopted in Experiment 1. The minimum sample size required by the experimental design (see the next section) was $N = 25$. We tested thirty-two participants (*Mean age* = 23 years, $SE = 0.28$, 12 males). Participants were not aware of the purpose of the experiment, were volunteers, and provided informed consent. The local Ethics Committee for Psychological Research approved the study, which was conducted in accordance with the Declaration of Helsinki.

2.2.2. Apparatus, stimuli, and procedure

The apparatus consisted of a desktop PC equipped with E-Prime and connected to a standard keyboard and a monitor (1920 px width × 1080 px height) placed 57 cm away from the participant. Symbolic cues consisted of two black arrows both pointing leftwards or rightwards (see Fig. 1) and occupying an area of about 55 px width × 40 px height. Screen background was grey (R = 128, G = 128, B = 128).

Each trial started with a central black fixation cross (size: 1°) for 900 ms. After that, the two arrows appeared for 200 ms pointing both leftwards or rightwards (as in Experiment 1, in the 'intermixed' condition the direction of the arrows randomly changed across trials whereas, in the 'blocked' condition, it was maintained constant within a block of trials). Then, a peripheral target stimulus appeared ± 14° either leftwards or rightwards with respect to the centre of the screen. The target was a black letter (i.e., 'L' or 'T'; font:

[1] In preliminary analyses, we also included block order as an additional factor; however, it was not further considered because no interactions with the congruency factor emerged ($ps > 0.072$).

Table 1
Mean latencies (in ms) and accuracy (proportion correct) emerged in Experiments 1 and 3; they are reported separately for condition, SOA, and congruency (C = congruent; I = incongruent); SEM are reported in parentheses. Columns 'D' report the absolute value of the difference between Congruent and Incongruent trials. Please note that, in Experiment 1, the best model fitting accuracy data was the null model (i.e., the model which included only 'participant' as a random effect). For completeness, we have reported the mean values computed from the model which included the three experimental factors.

	Intermixed condition						Blocked condition					
	200-ms SOA			700-ms SOA			200-ms SOA			700-ms SOA		
	C	I	D	C	I	D	C	I	D	C	I	D
Experiment 1												
RTs	614 (9.61)	624 (9.61)	10	569 (9.61)	587 (9.61)	18	622 (9.42)	632 (9.42)	10	572 (9.42)	593 (9.42)	21
Accuracy	0.966 (0.005)	0.966 (0.005)	0	0.969 (0.004)	0.971 (0.004)	0.002	0.968 (0.005)	0.964 (0.005)	0.004	0.964 (0.005)	0.964 (0.005)	0
Experiment 3												
RTs	594 (9.96)	610 (9.96)	16	533 (9.95)	559 (9.96)	26	590 (9.08)	598 (9.08)	8	526 (9.07)	540 (9.07)	14
Accuracy	0.944 (0.008)	0.941 (0.008)	0.003	0.962 (0.005)	0.947 (0.007)	0.015	0.944 (0.007)	0.941 (0.008)	0.003	0.954 (0.006)	0.946 (0.007)	0.008

Arial; size: 0.8°). A single SOA was used to simplify the experimental design. This change should result in increasing the similarity among trials in the blocked condition, thus further diminishing contextual variability and, in turn, the likelihood of arrow processing. Participants were requested to maintain their gaze at the centre of the screen for the whole duration of the trial, to ignore the arrows as they were not predictive of the target location, and to discriminate the letter by providing fast and accurate responses (time limit was set to 3000 ms). Responses were delivered through the keyboard by using the 'D' and the 'K' keys (the association between keys and the target letters was counterbalanced across participants). Feedback was delivered when a missed or a wrong response occurred, namely the black words 'TOO SLOW' or 'NO' (font: Arial; size: 18 points) appeared for 500 ms in the centre of the screen. A practice block composed of 10 trials was followed by four experimental blocks, totalling 264 experimental trials.

2.2.3. Results

Data handling and analyses were the same as those adopted in the previous experiment. Missing (0.05 % of trials) and wrong responses were removed (3.54 % of trials; these latter responses were analysed separately). Trials with a correct response and a latency smaller than 150 ms or greater than 1500 ms were also eliminated (0.29 % of trials).[2] The experimental design included congruency (2: congruent vs. incongruent) and condition (2: intermixed vs. blocked) as within-participant factors.

The minimum number of observations per experimental condition was 1962 and therefore sufficient power was achieved. The best model included congruency and condition, and their interactions as fixed effects, and the random effect was the intercept for participants and the by-participant random slope for the effect of condition. The main effect of congruency was significant, $F(1, 7807.6) = 47.0944$, $p < 0.001$, $\eta_p^2 = 0.436$, as latencies were smaller on congruent ($M = 548$ ms, $SE = 11.6$) than on incongruent ($M = 566$ ms, $SE = 11.6$) trials. The main effect of condition ($p = 0.0945$), as well as the condition × congruency interaction ($p = 0.446$; see also Table 2), were not significant.

As for errors, the best model included congruency, condition, and their interactions as fixed effects, and the random effects were the intercept for participants and the by-participant random slope for the effect of condition. No significant results emerged ($ps > 0.299$; see also Table 2).

2.2.4. Discussion

The present results confirm the findings that emerged in the previous experiment, indicating that, even in a lab-based setting, invariant arrows give rise to a significant orienting effect of comparable magnitude with respect to that elicited by arrows randomly changing direction from trial to trial. In the next experiment, we further tested the boundaries of automated symbolic orienting by providing an additional central cue consisting of a 100 % valid direction word (i.e., 'left' or 'right') prior to the onset of the arrows (also see Dalmaso et al., 2024). In so doing, we aimed to provide participants in advance with fully reliable knowledge about the upcoming target location, thus further discouraging the processing of the arrows (see Dalmaso et al., 2020; Galfano et al., 2012).

[2] In preliminary analyses, we also included block order as an additional factor; however, it was not further considered because no interactions with the congruency factor were found ($ps > 0.458$).

Table 2
Mean latencies (in ms) and accuracy (proportion correct) emerged in Experiments 2 and 4; they are reported separately for condition, SOA, and congruency (C = congruent; I = incongruent); SEM are reported in parentheses. Columns 'D' report the absolute value of the difference between Congruent and Incongruent trials. Please note that, in Experiment 4, the best model fitting accuracy data was the null model (i.e., the model which included only 'participant' as a random effect). For completeness, we have reported the mean values computed from the model which included the three experimental factors.

	Intermixed condition			Blocked condition		
	C	I	D	C	I	D
Experiment 2						
RTs	552 (11.1)	572 (11.1)	20	544 (12.8)	560 (12.8)	16
Accuracy	0.979 (0.005)	0.979 (0.005)	0	0.974 (0.005)	0.974 (0.005)	0
Experiment 4						
RTs	571 (17.5)	596 (17.5)	25	566 (17.8)	581 (17.8)	15
Accuracy	0.964 (0.007)	0.964 (0.007)	0	0.968 (0.006)	0.963 (0.007)	0.005

2.3. Experiment 3

2.3.1. Participants

Sample size was determined a priori following the same guidelines (Brysbaert & Stevens, 2018) adopted in the previous two experiments. Since the number of experimental cells was the same as in Experiment 1, we decided to include the same number of participants in this study. We therefore tested eighty new participants (*Mean age* = 24 years, *SE* = 0.32, 39 males). The participants were not aware of the purpose of the experiment, were volunteers, and provided informed consent. The study was approved by the local Ethics Committee for Psychological Research and conducted in accordance with the Declaration of Helsinki.

2.3.2. Apparatus, stimuli, and procedure

Apparatus and stimuli were the same as those used in Experiment 1. The task was similar to that used in Experiment 1 and, also in this case, the target was a black line oriented either horizontally or vertically (width: 40 px; height: 12 px). We only added a direction black word (i.e., 'LEFT' or 'RIGHT'; font: Arial; size: 0.7 normalised units) whose meaning was 100 % predictive of the location of the target. The word appeared centrally for 1000 ms before the presentation of the arrows without the heads.

2.3.3. Results

Data handling and analyses were the same as in Experiment 1. Missing (0.64 % of trials) and wrong responses were removed (7.97 % of trials; these latter responses were analysed separately). Trials with a correct response and latencies smaller than 150 ms or greater than 1500 ms were also eliminated (0.54 % of trials).[3]

The minimum number of observations per experimental condition was 2299 and therefore sufficient power was achieved. The best model included congruency, SOA, and condition, and their interactions as fixed effects, and the random effect was the intercept for participants and the by-participant random slope for the effect of condition. The main effect of congruency was significant, $F(1, 18443.1) = 65.3306$, $p < 0.001$, $\eta_p^2 = 0.347$, as latencies were smaller on congruent ($M = 561$ ms, $SE = 8.77$) than on incongruent ($M = 577$ ms, $SE = 8.77$) trials, as well as the main effect of SOA, $F(1, 18442.2) = 837.0229$, $p < 0.001$, $\eta_p^2 = 0.647$, as latencies were smaller at the 700-ms ($M = 539$ ms, $SE = 8.77$) than at the 200-ms SOA ($M = 598$ ms, $SE = 8.77$), consistent with a foreperiod effect. The congruency × SOA interaction was also significant, $F(1, 18441.4) = 4.2324$, $p = 0.04$, $\eta_p^2 = 0.030$; the comparisons between congruent vs. incongruent trials conducted separately for each SOA were both significant ($ps < 0.001$), but the difference was greater at the 700-ms SOA (21 ms vs. 12 ms), in line with Experiment 1. The congruency × condition interaction was also significant, $F(1, 18441.9) = 6.1929$, $p = 0.013$, $\eta_p^2 = 0.068$; the comparisons between congruent vs. incongruent trials conducted separately for each condition were both significant ($ps < 0.001$), but the difference was greater in the random condition (21 ms vs. 11 ms). No other significant results emerged ($ps > 0.09$; see also Table 1).

As for errors, the best model included congruency, SOA, and condition, and their interactions as fixed effects, and the random effects were the intercept for participants and the by-participant random slope for the effect of condition. The main effect of SOA was non-significant ($p = 0.055$), as well as the other results ($ps > 0.213$; see also Table 1).

2.3.4. Discussion

The main effect of congruency was significant and pointed to a clear arrow-driven cueing effect. However, unlike Experiments 1

[3] In preliminary analyses, we also included block order as additional factor; however, it was not further considered because no interactions with the congruency factor emerged ($ps > 0.070$).

and 2, the results of the present experiment showed that orienting of attention driven by uninformative arrows was smaller in the blocked as compared to the intermixed condition, thus suggesting that automated symbolic orienting might be slightly weakened in the presence of conditions aimed to overcome automaticity. To test the robustness of this pattern, in the next experiment we aimed to test this modulation using the same conservative approach adopted in Experiment 2, namely a lab-based study with a single SOA, no apparent movement and a discrimination task based on non-spatial features.

2.4. Experiment 4

2.4.1. Participants

Sample size was determined a priori following the same guidelines (Brysbaert & Stevens, 2018) adopted in the previous three experiments. Since the number of experimental cells was the same as in Experiment 2, we decided to include the same number of participants in this study. Hence, the sample included thirty-two new participants (*Mean age* = 23 years, *SE* = 0.31, 12 males), all of whom were naïve as to the purpose of the experiment, were volunteers and provided informed consent. The local Ethics Committee for Psychological Research approved the study, which was conducted in accordance with the Declaration of Helsinki.

2.4.2. Apparatus, stimuli, and procedure

Apparatus and stimuli were the same as those used in Experiment 2. The task was similar to that used in Experiment 2 and, also in this case, the target was the black letter ‘L’ or ‘T’ (font: Arial; size: 0.8°). We only added a direction black word (i.e., ‘LEFT’ or ‘RIGHT’; font: Arial; size: 28 points) whose meaning was 100 % predictive of the location of the target. The word appeared centrally for 1000 ms, before the presentation of the arrows.

2.4.3. Results

Data handling and analyses were the same as in Experiment 2. Missing (0.02 % of trials) and wrong responses were removed (4.76 % of trials; these latter responses were analysed separately). Trials with a correct response and a latency smaller than 150 ms or greater than 1500 ms were also eliminated (0.73 % of trials).[4]

The minimum number of observations per experimental condition was 1929 and therefore sufficient power was achieved. The best model included congruency and condition, and their interactions as fixed effects, and the random effect was the intercept for participants and the by-participant random slope for the effect of condition. The main effect of congruency was significant, $F(1, 7674.2) = 33.0407, p < 0.001, \eta_p^2 = 0.436$, as latencies were smaller on congruent ($M = 568$ ms, $SE = 16.5$) than on incongruent ($M = 589$ ms, $SE = 16.5$) trials. No other significant results emerged ($ps > 0.139$; see also Table 2).

As for errors, the best model was the null model, namely the one only including participant as random effect.

2.4.4. Discussion

The results of the present experiment were clear-cut and, in line with Experiments 1 and 2, showed a significant arrow-driven orienting of attention in the absence of any modulatory role of the blocked vs. intermixed condition. This, in turn, indicates that even when participants were provided in advance with 100 % valid information as to target location, they could not help shifting their attention following the direction indicated by arrows.

3. General discussion

The aim of the present study was to further investigate the nature of automated symbolic orienting. In particular, our goal was to test some of the boundary conditions for orienting of attention driven by uninformative arrows. Previous studies mainly used manipulations of expectancies, in which participants are informed that the target will appear in the location opposite to that indicated by the arrow in the vast majority (or totality) of trials (e.g., Friesen et al., 2004; Schmitz et al., 2024; Tipples, 2008). Although such an approach provides valuable information, it also presents some limitations, in that it requires making the arrow task-relevant (i.e., in order to foresee the most likely location for the target to appear, it is strategically advantageous for the participants to deliberately process the arrow). Here, we took a different strategy to test resistance to suppression. Arrow stimuli presented in the current experiments were always uninformative with respect to the target location (i.e., participants knew they were unreliable cues). Importantly, in one condition, arrows were further drained of any informational value, as arrow direction never changed within a given block of trials (blocked condition). In so doing, we aimed to create the conditions that might bolster participants’ tendency to ignore the arrows. This, in turn, may eventually counteract the arrow-driven orienting effect expected in a classic condition in which arrow direction unpredictably changes on a trial-by-trial basis (intermixed condition). In Experiment 1, a significant arrow-driven effect of comparable magnitude was observed irrespective of condition. This pattern was also obtained in Experiment 2, in which different methodological changes were applied to the experimental procedure in order to set up a more stringent test. Most notably, unlike Experiment 1, the task required letter-based non-spatial discrimination, and no apparent movement contaminated attention cueing effects. Taken together, the results of Experiments 1 and 2 support the idea that automated symbolic orienting, as instantiated in arrow-driven cueing, seems to be insensitive to contextual manipulations aimed at minimising the informative value of the spatial cues.

[4] In preliminary analyses, we also included block order as an additional factor; however, it was not further considered because no interactions with the congruency factor emerged ($ps > 0.523$).

An additional strategy to further defuse the informative value of arrows consists of providing the participants in advance with a different cue stimulus conveying 100 % valid information about the location of the upcoming target (see, e.g., Dalmaso et al., 2020; Galfano et al., 2012). In Experiments 3 and 4, we adopted this approach and used direction words. Importantly, direction words have been previously shown to be powerful cues because they elicit orienting of attention even when they are not informative (e.g., Hommel et al., 2001). In both experiments, despite participants were warned about the exact target location in advance, a robust and significant arrow-driven cueing effect emerged. Interestingly, in Experiment 3, such a phenomenon appeared to be larger in the intermixed condition as compared to the blocked condition. On the one hand, this could be seen as evidence that the blocked condition weakened—albeit without eliminating—the cueing effect elicited by arrows. However, on the other hand, in Experiment 4, in which the same strict methodological precautions implemented in Experiment 2 were adopted, this modulation did not emerge, in line with Experiments 1 and 2. Hence, three out of four experiments supported the view that the orienting effects elicited by arrow cues were insensitive to the intermixed vs. blocked condition. Therefore, we are driven to believe that the congruency × condition interaction observed in Experiment 3 could be more likely considered far from being solid, and therefore should be interpreted with extreme caution. Overall, the present findings cast novel evidence in support of the notion that automated symbolic orienting is resistant to suppression in that it survives even when the context should emphasise the uninformative nature of the arrows while also creating ideal conditions to boost participants' tendency to ignore them.

The present results fit well with the notion that arrows are important communicative signals and the ability to effortlessly interpret them may prove extremely important when navigating daily-life circumstances. It is reasonable to assume that attentional mechanisms are tuned to prioritise these signals as a result of an overlearning process (e.g., Ristic & Kingstone, 2012), even though they have no biological relevance, unlike eye gaze or pointing gestures (Capozzi & Ristic, 2018).

The processing of gaze and arrows has often been investigated in the same set of spatial cueing experiments, based on the observation that they are both central cues that push attention away from fixation (see Chacón-Candia et al., 2023, for a review). This has been done, for instance, to address whether orienting of attention driven by social signals is damaged in patients suffering from different psychopathologies or neurological conditions (e.g., Akiyama et al., 2008; Dalmaso et al., 2015; Marotta et al., 2014; Vascello et al., 2024). More interestingly to the purpose of the present study, several authors have attempted to clarify the extent to which gaze- and arrow-driven orienting share common processes in healthy individuals (Chacón-Candia et al., 2023). Many studies addressing different facets of automaticity in spatial attention have provided evidence that gaze-driven and arrow-driven orienting are very similar in magnitude (e.g., Dalmaso et al., 2020; Dalmaso, Castelli, et al., 2023a; Galfano et al., 2012; Kuhn & Kingstone, 2009; Stevens et al., 2008; see Chacón-Candia et al., 2023, for a *meta*-analysis). However, evidence also shows that when arrow and gaze cues are simultaneously presented in a cueing task, the spatial information conveyed by arrows is harder to suppress than that of gaze (Besner et al., 2021), further attesting the power of arrows in shaping attentional processes. Interestingly, Dalmaso et al. (2024) have recently used contextual manipulations similar to those implemented in the present study by focusing on gaze-driven orienting. Overall, their results display a consistent pattern with respect to the one observed with arrows in the current experiments.

In summary, according to the available evidence illustrated above, one may be tempted to conclude that eye gaze and arrows are treated similarly by the attention system, at least when specific circumstances are met. However, it should also be noted that another stream of studies comparing arrows and gaze has shown that the two stimuli can also elicit diverging attentional responses both in spatial cueing paradigms and in spatial Stroop tasks (e.g., Cañadas & Lupiáñez, 2012; Dalmaso, Galfano et al., 2023b; Marotta et al., 2018). For instance, it has been shown that whereas attention shifts induced by arrows would spread across the whole surface of a target object, eye gaze would instead orient attention to a specific spatial location within a target object (Marotta et al., 2012). Although arrow and gaze can both push attention in a strongly reflexive manner, a likely remarkable difference between arrows and gaze cueing lies in their developmental trajectories. In this regard, whereas orienting of attention elicited by eye gaze is present in very young infants (e.g., Farroni et al., 2004), there is evidence suggesting that only children older than 5 years seem capable to orient their attention as a function of the conceptual meaning of arrows (Jakobsen et al., 2013). This, in turn, suggests that gaze-driven orienting is likely relying on hard-wired mechanisms, while arrow-driven orienting mainly reflects learning-based processes. In other words, while it is widely accepted that both signals produce reflexive shifts of attention, gaze-driven orienting likely relies on *automatic* processing whereas, on the other hand, arrow-driven orienting may be based on *automated* processes following massive practice (Ristic & Kingstone, 2012).

To conclude, the present set of experiments provides evidence indicating that arrows are very strong cues for spatial attention, and supports their use as symbols to communicate spatial information also in applied contexts in which such knowledge is implemented to promote usability and effective interactions with digital devices (e.g., Ouyang & Zhou, 2019).

CRediT authorship contribution statement

Mario Dalmaso: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Giovanni Galfano:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Conceptualization. **Luigi Castelli:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Conceptualization.

Funding

This work was supported by the Italian Ministry of University and Research (MUR) [grant number: PRIN 2022, 2022H4WZKN].

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data, experiment codes, and stimuli associated with this work can be found here: http://doi.org/10.17605/OSF.IO/RP4EU

References

Akiyama, T., Kato, M., Muramatsu, T., Maeda, T., Hara, T., & Kashima, H. (2008). Gaze-triggered orienting is reduced in chronic schizophrenia. *Psychiatry Research, 158*(3), 287–296. https://doi.org/10.1016/j.psychres.2006.12.004

Bartoń, K. (2024). MuMIn: Multi-Model Inference. *R package version, 1*(48), 4. https://CRAN.R-project.org/package=MuMIn.

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software, 67*(1). https://doi.org/10.18637/jss.v067.i01

Bertelson, P., & Tisseyre, F. (1968). The time-course of preparation with regular and irregular foreperiods. *The Quarterly Journal of Experimental Psychology, 20*(3), 297–300. https://doi.org/10.1080/14640746808400165

Besner, D., McLean, D., & Young, T. (2021). Do eyes and arrows elicit automatic orienting? Three mutually exclusive hypotheses and a test. *Quarterly Journal of Experimental Psychology, 74*(7), 1164–1169. https://doi.org/10.1177/1747021821998572

Bridges, D., Pitiot, A., MacAskill, M. R., & Peirce, J. W. (2020). The timing mega-study: Comparing a range of experiment generators, both lab-based and online. *PeerJ, 8*, e9414. https://doi.org/10.7717/peerj.9414

Brysbaert, M., & Stevens, M. (2018). Power analysis and effect size in mixed effects models: A tutorial. *Journal of Cognition, 1*(1), 1–20. https://doi.org/10.5334/joc.10

Burigat, S., Chittaro, L., & Gabrielli, S. (2008). Navigation techniques for small-screen devices: An evaluation on maps and web pages. *International Journal of Human-Computer Studies, 66*(2), 78–97. https://doi.org/10.1016/j.ijhcs.2007.08.006

Cañadas, E., & Lupiáñez, J. (2012). Spatial interference between gaze direction and gaze location: A study on the eye contact effect. *Quarterly Journal of Experimental Psychology, 65*(8), 1586–1598. https://doi.org/10.1080/17470218.2012.659190

Capozzi, F., & Ristic, J. (2018). How attention gates social interactions. *Annals of the New York Academy of Sciences, 1426*(1), 179–198. https://doi.org/10.1111/nyas.13854

Carraro, L., Dalmaso, M., Castelli, L., & Galfano, G. (2015). The politics of attention contextualized: Gaze but not arrow cuing of attention is moderated by political temperament. *Cognitive Processing, 16*, 309–314. https://doi.org/10.1007/s10339-015-0661-5

Chacón-Candia, J. A., Román-Caballero, R., Aranda-Martín, B., Casagrande, M., Lupiáñez, J., & Marotta, A. (2023). Are there quantitative differences between eye-gaze and arrow cues? A meta-analytic answer to the debate and a call for qualitative differences. *Neuroscience & Biobehavioral Reviews, 144*, Article 104993. https://doi.org/10.1016/j.neubiorev.2022.104993

Cole, G. G., & Kuhn, G. (2010). What the experimenter's prime tells the observer's brain. *Attention, Perception, & Psychophysics, 72*, 1367–1376. https://doi.org/10.3758/APP.72.5.1367

Dalmaso, M., Castelli, L., Bernardini, C., & Galfano, G. (2023a). Can masked gaze and arrow stimuli elicit overt orienting of attention? A registered report. *Consciousness and Cognition, 109*, Article 103476. https://doi.org/10.1016/j.concog.2023.103476

Dalmaso, M., Castelli, L., Franchetti, L., Carli, L., Todisco, P., Palomba, D., & Galfano, G. (2015). Altered orienting of attention in anorexia nervosa. *Psychiatry Research, 229*(1–2), 318–325. https://doi.org/10.1016/j.psychres.2015.06.044

Dalmaso, M., Castelli, L., & Galfano, G. (2020). Early saccade planning cannot override oculomotor interference elicited by gaze and arrow distractors. *Psychonomic Bulletin & Review, 27*(5), 990–997. https://doi.org/10.3758/s13423-020-01768-x

Dalmaso, M., Castelli, L., & Galfano, G. (2021). Increased gaze cueing of attention during COVID-19 lockdown. *IScience, 24*(11). https://doi.org/10.1016/j.isci.2021.103283

Dalmaso, M., Galfano, G., & Castelli, L. (2023b). Are eyes special? Gaze, but not pointing gestures, elicits a reversed congruency effect in a spatial Stroop task. *Attention, Perception, & Psychophysics, 85*(8), 2547–2552. https://doi.org/10.3758/s13414-023-02774-6

Dalmaso, M., Galfano, G., & Castelli, L. (2024). Testing the effects of gaze distractors with invariant spatial direction on attention cueing. *Quarterly Journal of Experimental Psychology, 77*, 1544–1554. https://doi.org/10.1177/17470218231203963

Eimer, M. (1997). Uninformative symbolic cues may bias visual-spatial attention: Behavioral and electrophysiological evidence. *Biological Psychology, 46*(1), 67–71. https://doi.org/10.1016/S0301-0511(97)05254-X

Farroni, T., Massaccesi, S., Pividori, D., & Johnson, M. H. (2004). Gaze following in newborns. *Infancy, 5*(1), 39–60. https://doi.org/10.1207/s15327078in0501_2

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*(4), 1030–1044. https://doi.org/10.1037/0096-1523.18.4.1030

Friesen, C. K., Ristic, J., & Kingstone, A. (2004). Attentional effects of counterpredictive gaze and arrow cues. *Journal of Experimental Psychology: Human Perception and Performance, 30*, 319–329. https://doi.org/10.1037/0096-1523.30.2.319

Galfano, G., Dalmaso, M., Marzoli, D., Pavan, G., Coricelli, C., & Castelli, L. (2012). Eye gaze cannot be ignored (but neither can arrows). *The Quarterly Journal of Experimental Psychology, 65*(10), 1895–1910. https://doi.org/10.1080/17470218.2012.663765

Gayet, S., Van der Stigchel, S., & Paffen, C. L. (2014). Seeing is believing: Utilization of subliminal symbols requires a visible relevant context. *Attention, Perception, & Psychophysics, 76*, 489–507. https://doi.org/10.3758/s13414-013-0580-4

Gibson, B. S., & Bryant, T. A. (2005). Variation in cue duration reveals top-down modulation of involuntary orienting to uninformative symbolic cues. *Perception & Psychophysics, 67*, 749–758. https://doi.org/10.3758/BF03193530

Guzzon, D., Brignani, D., Miniussi, C., & Marzi, C. A. (2010). Orienting of attention with eye and arrow cues and the effect of overtraining. *Acta Psychologica, 134*(3), 353–362. https://doi.org/10.1016/j.actpsy.2010.03.008

Hayward, D. A., & Ristic, J. (2016). Automated symbolic orienting is not modulated by explicit temporal attention. *Acta Psychologica, 171*, 93–98. https://doi.org/10.1016/j.actpsy.2016.10.004

Hommel, B., Pratt, J., Colzato, L., & Godijn, R. (2001). Symbolic control of visual attention. *Psychological Science, 12*(5), 360–365. https://doi.org/10.1111/1467-9280.00367

Jakobsen, K. V., Frick, J. E., & Simpson, E. A. (2013). Look here! The development of attentional orienting to symbolic cues. *Journal of Cognition and Development, 14*(2), 229–249. https://doi.org/10.1080/15248372.2012.666772

Jonides, J. (1981). Voluntary versus automatic control over the mind's eye's movement. In J. B. Long, & A. D. Baddeley (Eds.), *Attention and Performance IX* (pp. 187–203). Hillsdale, NJ: Erlbaum.

Kuhn, G., & Kingstone, A. (2009). Look away! Eyes and arrows engage oculomotor responses automatically. *Attention, Perception, and Psychophysics, 71*(2), 314–327. https://doi.org/10.3758/APP.71.2.314

Lenth, R. V. (2016). Least-squares means: The R package lsmeans. *Journal of Statistical Software, 69*(1), 1–33. https://doi.org/10.18637/jss.v069.i01

Marotta, A., Casagrande, M., Rosa, C., Maccari, L., Berloco, B., & Pasini, A. (2014). Impaired reflexive orienting to social cues in attention deficit hyperactivity disorder. *European Child & Adolescent Psychiatry, 23*, 649–657. https://doi.org/10.1007/s00787-013-0505-8

Marotta, A., Lupiánez, J., Martella, D., & Casagrande, M. (2012). Eye gaze versus arrows as spatial cues: Two qualitatively different modes of attentional selection. *Journal of Experimental Psychology: Human Perception and Performance, 38*(2), 326–335. https://doi.org/10.1037/a0023959

Marotta, A., Román-Caballero, R., & Lupiáñez, J. (2018). Arrows don't look at you: Qualitatively different attentional mechanisms triggered by gaze and arrows. *Psychonomic Bulletin & Review, 25*, 2254–2259. https://doi.org/10.3758/s13423-018-1457-2

McKay, K. T., Grainger, S., Coundouris, S., Skorich, D., & Henry, J. (2021). Visual attentional orienting by eye gaze: A meta-analytic review of the gaze-cueing effect. *Psychological Bulletin, 147*(12), 1269–1289. https://doi.org/10.1037/bul0000353

Ouyang, X., & Zhou, J. (2019). How to help older adults move the focus on a smart TV? Exploring the effects of arrow hints and element size consistency. *International Journal of Human-Computer Interaction, 35*(15), 1420–1436. https://doi.org/10.1080/10447318.2018.1534346

Posner, M. I., Snyder, C. R., & Davidson, B. J. (1980). Attention and the detection of signals. *Journal of Experimental Psychology: General, 109*(2), 160–174. https://doi.org/10.1037/0096-3445.109.2.160

Ristic, J., & Kingstone, A. (2009). Rethinking attentional development: Reflexive and volitional orienting in children and adults. *Developmental Science, 12*(2), 289–296. https://doi.org/10.1111/j.1467-7687.2008.00756.x

Ristic, J., & Kingstone, A. (2012). A new form of human spatial attention: Automated symbolic orienting. *Visual Cognition, 20*(3), 244–264. https://doi.org/10.1080/13506285.2012.658101

Ristic, J., Friesen, C. K., & Kingstone, A. (2002). Are eyes special? It depends on how you look at it. *Psychonomic Bulletin & Review, 9*, 507–513. https://doi.org/10.3758/BF03196306

Schmitz, I., Strauss, H., Reinel, L., & Einhäuser, W. (2024). Attentional cueing: Gaze is harder to override than arrows. *PLoS ONE, 19*(3), Article e0301136. https://doi.org/10.1371/journal.pone.0301136

Sternberg, S. (2001). Separate modifiability, mental modules, and the use of pure and composite measures to reveal them. *Acta Psychologica, 106*(1–2), 147–246. https://doi.org/10.1016/S0001-6918(00)00045-7

Stevens, S. A., West, G. L., Al-Aidroos, N., Weger, U. W., & Pratt, J. (2008). Testing whether gaze cues and arrow cues produce reflexive or volitional shifts of attention. *Psychonomic Bulletin & Review, 15*(6), 1148–1153. https://doi.org/10.3758/PBR.15.6.1148

Tipples, J. (2002). Eye gaze is not unique: Automatic orienting in response to uninformative arrows. *Psychonomic Bulletin & Review, 9*(2), 314–318. https://doi.org/10.3758/BF03196287

Tipples, J. (2008). Orienting to counterpredictive gaze and arrow cues. *Perception & Psychophysics, 70*(1), 77–87. https://doi.org/10.3758/PP.70.1.77

Yokoyama, T., Kato, R., Inoue, K., & Takeda, Y. (2022). Cuing effects by biologically and behaviorally relevant symbolic cues. *Japanese Psychological Research, 64*(3), 308–319. https://doi.org/10.1111/jpr.12318

Vascello, M. G., Pizzighello, S., Spada, M. S., Martinuzzi, A., & Dalmaso, M. (2024). Social face processing in chronic severe traumatic brain injury: Altered decoding of emotions and mental states but preserved gaze cueing of attention. *Neuropsychologia, 108975*. https://doi.org/10.1016/j.neuropsychologia.2024.108975