Consciousness and Cognition 29 (2014) 56–67

Contents lists available at ScienceDirect

Consciousness and Cognition

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

From body shadows to bodily attention: Automatic orienting of tactile attention driven by cast shadows

Francesco Pavani [a,b,*], Paola Rigo [b], Giovanni Galfano [c,d]

[a] Center for Mind/Brain Sciences, University of Trento, Italy
[b] Department of Psychology and Cognitive Science, University of Trento, Italy
[c] Department of Developmental and Social Psychology, University of Padua, Italy
[d] Center for Cognitive Neuroscience, University of Padua, Italy

ARTICLE INFO

Article history:
Received 25 November 2013

Keywords:
Body perception
Shadow
Spatial attention
Multisensory
Touch
Vision

ABSTRACT

Body shadows orient attention to the body-part casting the shadow. We have investigated the automaticity of this phenomenon, by addressing its time-course and its resistance to contextual manipulations. When targets were tactile stimuli at the hands (Exp.1) or visual stimuli near the body-shadow (Exp.2), cueing effects emerged regardless of the delay between shadow and target onset (100, 600, 1200, 2400 ms). This suggests a fast and sustained attention orienting to body-shadows, that involves both the space occupied by shadows (extra-personal space) and the space the shadow refers to (own body). When target type became unpredictable (tactile or visual), shadow-cueing effects remained robust only for tactile targets, as visual stimuli showed no overall reliable effects, regardless of whether they occurred near the shadow (Exp.3) or near the body (Exp.4). We conclude that mandatory attention shifts triggered by body-shadows are limited to tactile targets and, instead, are less automatic for visual stimuli.

1. Introduction

Shadows have fascinated philosophers, scientists and novelists for many centuries (for review see Casati, 2003). In recent years, the processing of shadows has also been the target of an increasing number of studies in cognitive science, likely due to the growing body of evidence showing that information carried by shadows can serve a fundamental aid to several tasks performed in daily life. It is now widely acknowledged that shadows can be rapidly processed by our visual system (e.g., Elder, Trithart, Pintilie, & MacLean, 2004; Rensink & Cavanagh, 2004), and they can be efficiently used for object recognition in both humans (Castiello, 2001; Norman, Dawson, & Raines, 2000) and other animal species such as chicks (Mascalzoni, Regolin, & Vallortigara, 2009). In addition, several studies have shown that projected or cast shadows of objects not only greatly assist in defining the spatial arrangement of objects within a scene, in both dynamic and static contexts (e.g., Imura et al., 2006; Kersten, Mamassian, & Knill, 1997; Yonas & Granrud, 2006; see Mamassian, Knill, & Kersten, 1998, for a review), but can also play a role in modulating the dynamics of movement towards the casting objects (Bonfiglioli, Pavani, & Castiello, 2004).

In ecological contexts, shadows are projected not only by objects in the environment, but also by our own body. Converging neuroimaging data (Downing, Jiang, Shuman, & Kanwisher, 2001; Pourtois, Peelen, Spinelli, Seeck, & Vuilleumier, 2007;

* Corresponding author at: Center for Mind/Brain Sciences, University of Trento, Corso Bettini 31, 38068 Rovereto, Italy. Fax: +39 0464 808602.
E-mail address: francesco.pavani@unitn.it (F. Pavani).

http://dx.doi.org/10.1016/j.concog.2014.07.006
1053-8100/

Urgesi, Berlucchi, & Aglioti, 2004) suggest that body parts have dedicated cortical visual processing modules. Consistent with neuroimaging findings, behavioural evidence has also been reported showing that body parts seem to receive privileged processing resources compared to other objects (e.g., Igarashi, Kitagawa, Spence, & Ichihara, 2007; Ro, Friggel, & Lavie, 2007). Pavani and Castiello (2004) combined these two research domains and addressed the issue of whether shadows cast by our own body parts may act as a special category of shadow stimuli, as body shadows are evidence of high priority objects. They reasoned that, unlike object shadows, shadows cast by our own body part have the peculiarity of referring to a location (the body part casting them) for which we have proprioceptive and interoceptive experience, and may also be involved in the construction of the internal representation of body shape (body image) and boundaries (body schema). Pavani and Castiello exploited the visuo-tactile interference paradigm (e.g., Pavani, Spence, & Driver, 2000) and devised an experimental setup in which a task-irrelevant visual stimulus presented far and equidistant from both hands appeared in close proximity to the shadow cast by one of the two hands. The visual stimulus produced interference effects on the tactile localization task, particularly when tactile targets were delivered to the hand casting the shadow compared to when they were presented at the other hand. This exaggerated interference effect was unique to natural body shadows, as it was not modulated by the lateralised shadow when participants wore a shaped glove projecting an unnatural polygonal shadow. Pavani and Castiello interpreted the pattern of increased visuo-tactile interference as reflecting the fact that real body shadows exerted a binding between personal and extra-personal space.

Because cast shadows can be interpreted as evidence of things but they can hardly be defined as things in themselves, the findings of Pavani and Castiello (2004) raised the possibility that body shadows may also act as a visual cue that favours orienting of attention towards the body itself. This issue was addressed by Galfano and Pavani (2005), who devised a variant of the exogenous spatial cueing paradigm (see, e.g., Posner & Cohen, 1984) using hand shadows as spatially uninformative visual cues combined with a tactile localization task. Participants received tactile targets, unpredictably to the thumb or index finger of either hand, and were required to indicate whether the target was given on the thumb or index finger, regardless of the stimulated hand. At the same time they viewed the shadow of either the touched or the untouched hand, cast in front of them by a lateral light source. The shadow was entirely irrelevant to the task, because it indicated the actual stimulated hand on half of the trials only. Furthermore, participants were explicitly informed that the shadow conveyed no useful information for carrying out the task. Nonetheless, tactile localization performance was significantly better at the hand casting the shadow compared to the other hand. This result was taken as evidence that cast shadows of the body can elicit an involuntary orienting response towards the body parts casting them. Critically, when the cast shadow of the hand was replaced by the cast shadow of an object, shadow-driven orienting of attention became unreliable. Pavani and Galfano (2007) qualified this result further by showing that shadow-driven orienting was reliable for tactile targets presented at the hands, but did not emerge for visual targets presented near the hand or near the shadow. Thus, body shadows appear to specifically draw attention to tactile stimuli at the body part they refer to, rather than to the portion of space they cover.

These findings indicate that our cognitive system treats self-attributed body-shadows as a powerful attention cue, which orients resources to personal (body) space rather than external space. However, it remains unclear to what extent these mechanisms of attentional orienting triggered by body-shadows are truly mandatory. In the present research, we addressed this hypothesized automaticity of orienting of attention driven by body shadows in personal and extra-personal space, for tactile as well as visual stimuli. To this purpose, we focused on two important features considered critical when addressing automaticity in attention shifting over space. First, we wanted to establish whether the cueing effects reported previously (Galfano & Pavani, 2005; Pavani & Galfano, 2007) arose early in processing. As briefly anticipated earlier, one of the most striking aspects of the orienting of attention by body shadows is related to the fact that this phenomenon takes place despite the fact that the spatially non-predictive shadow cue is presented long in advance of the target. In all the experiments reported by both Galfano and Pavani (2005) and Pavani and Galfano (2007), the Stimulus Onset Asynchrony (SOA) separating shadow onset and target onset was 2750 milliseconds (ms). Importantly, cognitive phenomena are considered to be automatic to the extent that they arise early in processing. It is well known that orienting of visual attention in response to uninformative peripheral cues emerges rapidly after cue onset – with a cue-target SOA as short as 100 ms (e.g., Cheal, Lyon, & Gottlob, 1994; Müller & Rabbitt, 1989). Similar results have been reported for another type of spatial cue that is considered to induce automatic attention shifts, that is eye gaze (e.g., Driver et al., 1999; Friesen & Kingstone, 1998; Galfano et al., 2011). Hence, if shadow-driven orienting reflects automatic attention shifts, then our first general prediction was to observe such effect with a very short SOA.

A second important feature often considered for addressing automatic processes is resistance to contextual modulations (e.g., Bargh & Ferguson, 2000; Moors & De Houwer, 2006; Pasqualotto, Finucane, & Newell, 2013; Ristic & Kingstone, 2005; Zbrodoff & Logan, 1986). That is, orienting of attention can be said to occur in a strongly automatic fashion if and only if it proves largely insensitive to manipulations of experimental setting.

To test these predictions, we ran four experiments in which we used the same paradigm employed by Pavani and Galfano (2007), but we included a range of different SOAs to assess the time course of shadow-driven orienting. SOAs values were 100, 600, 1200, and 2400 ms and were adopted from the literature on gaze-driven orienting (e.g., Friesen & Kingstone, 1998; Frischen & Tipper, 2004; Galfano et al., 2012). In Experiment 1, we aimed to assess the time course of shadow-driven orienting to tactile targets on the body. Participants were asked to discriminate whether the target was presented at the thumb or index finger of either hand. Participants were fully informed that the target was equally likely to be presented to the hand casting the shadow and the other hand, which rendered the shadow cue uninformative. In Experiment 2, we addressed the time course of shadow-driven orienting in extra-personal space, by using visual targets presented near the shadows. In Experiment 3, both tactile and visual targets were used, which allowed for addressing *both personal and extra-personal orienting* in the same experiment. This manipulation allowed for testing whether orienting mediated by body-shadows is context dependent (i.e., affected by manipulations of the experimental settings). In the final experiment, we intermixed again tactile and visual targets, but visual targets were also presented in personal space, adjacent to tactile targets (also see Pavani & Galfano, 2007). This final manipulation allowed us to disentangle whether any shadow orienting effect in personal space emerged regardless of the sensory modality (tactile vs. visual) of the target, or was instead specific for touches on the body.

2. Methods

2.1. Experiment 1: tactile targets in personal space

In Experiment 1, we assessed automaticity of shadow-driven orienting by studying the time-course of this phenomenon when only tactile targets were presented on the body.

2.1.1. Participants

Nineteen undergraduate students at the University of Trento participated in the study (8 males and 11 females; mean age 23 years, SD 6; one left-handed by self-report). All were unaware of the purpose of the experiment, gave their informed consent and had normal or corrected-to-normal vision. The study was conducted in accordance with the 1964 Declaration of Helsinki.

2.1.2. Stimuli and apparatus

All experiments were conducted in a darkened room. Participants sat in front of a table with their forearms laid on two slanted supports made of polystyrene and cardboard (33.5 cm in width, 14.5 cm in length, and 15.5 cm in height) attached to the tabletop and separated by 37 cm. A green Light Emitting Diode (LED) attached to the table-top at 69 cm from the participants' trunk and aligned with their mid-sagittal plane served as the visual fixation point. A large (92 cm in length, 65 cm in width) sheet of white paper covered the table providing a uniform white surface on which fixation was visible only when lit. Three desk lamps with three-joint arms were placed on the table, each equipped with a fluorescent light-bulb suspended at approximately 80 cm from the table top. Two lamps mounted a 100 W fluorescent light-bulb each, oriented towards the table-top and placed 58 cm to the left or right with respect to the participants' mid-sagittal plane. These lamps served as light-sources for casting the shadows of participants' hands on the table surface (see Fig. 1). The third lamp mounted a 75 W fluorescent light-bulb, oriented towards the ceiling, and served to provide controlled central illumination on the setup.

Participants wore a fitting cotton-silicon sheath on thumb and index finger of each hand. A custom-built miniature solenoid (7.5 × 12 mm) was placed inside each sheath, in contact with each finger-tip. Single 50 ms pulses delivered separately

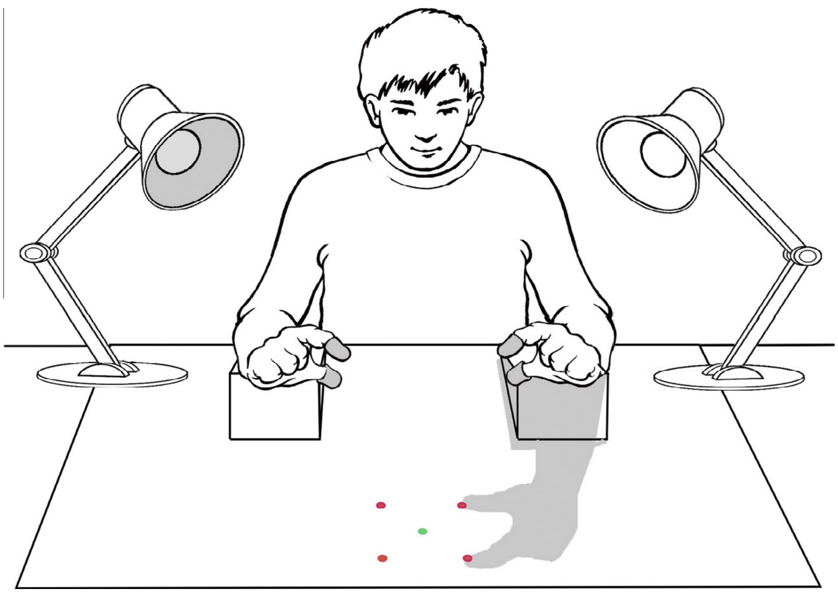

Fig. 1. Schematic drawing of the experimental setup. For illustrating purposes the shadow of the left hand only is shown. Also for illustrating purposes, the position of all red LEDs (visual targets in extra-personal space) is shown in the drawing. Visual targets were illuminated one at a time, and they were visible only when lit. The green led served as visual fixation in all experiment. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

at the four finger-tips served as tactile targets. Connecting wires for solenoids poked through the closed end of the sheath, and were fixed at the wrist with rubber-bands. Tactile stimulators, fixation LED, lamps and two foot-pedals for response collection were interfaced with an IBM compatible Pentium II Computer, equipped with an IO digital acquisition card (DAQ-DIO-24, National Instruments). A custom software on MATLAB written using Cogent libraries (http://www.vislab.ucl.ac.uk/Cogent/) was used for controlling the timing of events and recording both reaction times (RTs) and accuracy.

2.1.3. Procedure

Before the experiment started, all participants performed two miniblocks composed of four trials each, in which only tactile targets were presented. In case participants reported feeling large subjective differences in the intensity of the four tactile stimulations, the sheaths were removed, adjusted, and positioned again on the four fingers, and the miniblocks were repeated. Participants then performed one practice block of twenty trials before proceeding into the experimental blocks.

At the beginning of each practice and experimental block, shadows of both hands were cast on the table surface and participants were instructed to adopt a posture such that the cast shadow of their index fingers could overlap spatially with pencil marks drawn on the table top at the vertex of an imaginary square with sides of 14 cm, centred on visual fixation (see Fig. 1). Subsequently, only one of the two lamps was turned on during each trial.

Participants were instructed to start each trial by depressing two foot-pedals located respectively under the toe and heel of their right foot. When this was accomplished, visual fixation was turned on and after 1000 ms the shadow of one of the two hands was presented on the table surface through illumination of one of the two lamps. At variable SOAs (100, 600, 1200 or 2400 ms) from the appearance of the hand-shadow, a tactile target stimulus was presented at one of the stimulation sites on the hands. Participants were instructed to raise their toe in response to tactile targets at the index fingers, and their heel in response to tactile targets at the thumbs. Participants were instructed to react as fast and accurately as possible. Feedback was provided only for errors (wrong foot-pedal releases or no response within 1500 ms) and consisted of two brief flashes of the fixation LED, which otherwise remained on until the end of the trial. The inter-trial interval was 1000 ms. Participants were invited to take short breaks between blocks.

All participants were explicitly informed at the beginning of the experiment that shadows were completely task-irrelevant and not informative with regard to target location. In addition, they were strongly encouraged to maintain the posture acquired at the beginning of each block throughout the series of trials, and to keep their eyes at fixation. The experimenter remained in the room where the experiment took place in order to ensure that participants accorded with these instructions.

2.1.4. Design

Participants were tested in a 2×4 factorial design. The first factor was cue-target spatial congruency (congruent vs. incongruent). The second factor was the SOA between shadow and target onset (100, 600, 1200 or 2400 ms). The total number of trials was 384, divided into 4 experimental blocks of 96 trials each. In each block, there were 12 trials for each possible combination of cue-target spatial congruency and SOA. Shadow side and target location were totally unpredictable in each trial.

2.2. Experiment 2: visual targets in extra-personal space

In Experiment 2 we assessed automaticity of shadow-driven orienting studying the time-course of this phenomenon when visual targets were presented in isolation near the shadow (i.e., in extra-personal space). This had the purpose of assessing whether any early rising effect emerges similarly for the space the shadow refers to (i.e., the body) and the space the shadow occupies (i.e., extra-personal space).

2.2.1. Participants

Eighteen undergraduate students at the University of Trento participated in the study (10 males and 8 females; mean age 23 years, SD 3; one left-handed by self-report). All gave their informed consent and had normal or corrected-to-normal vision. Ten took part also in Experiment 1.

2.2.2. Stimuli, apparatus, procedure, design and data analysis

These were identical to Experiment 1, with the following exceptions. The cotton-silicon sheaths containing the miniature solenoids that were used for tactile stimulation in Experiment 1 were now removed from the setup. Instead, four red LEDs were added, attached to the table-top and placed at the vertex of an imaginary square with sides of 14 cm, centred on visual fixation. These red LEDs served as visual targets near the shadows and were switched on separately for 50 ms when needed. When hand-shadows were cast, the red LED at the vertices nearest to the participants overlapped with the shadow cast by the thumbs, whereas the visual targets at the furthest vertexes of the imaginary square overlapped with the shadow cast by the index fingers.

Participants performed one practice block of twenty trials before proceeding into the experimental blocks. As for Experiment 1, the target followed the appearance of the shadow by 100, 600, 1200 or 2400 ms. In this experiment, however, only visual targets were used. A visual target on the same side as the cast hand-shadow constituted a ‘congruent’ trial; whereas a visual target on the opposite side to the cast shadow constituted an ‘incongruent’ trial. Note that shadow side and target location were again totally unpredictable in each trial, thus there was no advantage for the participant to strategically orient attention towards the shadow.

2.3. Experiment 3: tactile targets in personal space, visual targets in extra-personal space

In Experiment 3, tactile and visual targets were intermixed in the same blocks of trials. This manipulation provided a further test for the automaticity of shadow-driven orienting by assessing whether this phenomenon was sensitive to contextual variables. Indeed, other spatial cues such as eye gaze are known to be only partially impervious to contextual factors such as the presence of other cueing stimuli within the same block of trials (see Pavan, Dalmaso, Galfano, & Castelli, 2011).

2.3.1. Participants

Twenty undergraduate students at the University of Trento participated in the study (4 males and 16 females; mean age 28.1 years, SD 3; all right-handed by self-report). All gave their informed consent and had normal or corrected-to-normal vision. None had taken part in the previous experiments.

2.3.2. Stimuli, apparatus, procedure, design and data analysis

These were identical to Experiment 2, with the following exceptions. The cotton-silicon sheaths containing the miniature solenoids that were used for tactile stimulation in Experiment 1 were now reintroduced in the setup. A visual target on the same side as the cast hand-shadow or a tactile target at the hand casting the shadow constituted a 'congruent' trial. By contrast, a visual target on the opposite side to the cast shadow or a tactile target at the hand not casting the shadow constituted an 'incongruent' trial. Note that tactile targets at the index fingers appeared above fixation as seen from the participants' viewpoint, whereas tactile target at the thumbs appeared below fixation. Shadow side and target location were again totally unpredictable in each trial, thus there was no advantage for the participant to strategically orient attention towards the shadow.

2.4. Experiment 4: tactile and visual targets in personal space

In Experiment 4, tactile and visual targets were intermixed in the same blocks of trials as in Experiment 3. However, unlike in the previous experiment, visual targets were now presented in personal space (see Pavani & Galfano, 2007). This manipulation allowed us to further test automaticity and to ascertain whether selective shadow-driven orienting is specific to the body space, or instead specific to tactile stimuli occurring on the body.

2.4.1. Participants

Nineteen undergraduate students at the University of Trento participated in the study (8 males and 11 females; mean age 27.9 years, SD 9; 17 right-handed by self-report, 2 ambidextrous). All gave their informed consent and had normal or corrected-to-normal vision. None had taken part in the previous experiments.

2.4.2. Stimuli, apparatus, procedure, design and data analysis

These were identical to Experiment 3, with the following exception. Due to equipment failure, tactile stimulators used in Experiments 1–3 were replaced with miniature solenoids (1.5×20 mm) of a different manufacturer (www.heijo.com/). Solenoids were fixed in contact with each finger-tip using medical adhesive tape. As in previous experiments, tactile stimuli consisted in 50 ms touches produced by the protrusion of small rod (2×2 mm).

Importantly, visual targets were now delivered at the hands (personal space) rather than near the shadows (extra-personal space). This was achieved by placing the four red LEDs used in the previous experiment next to each of the miniature solenoids. A visual target or a tactile target at the hand casting the shadow constituted a 'congruent' trial. By contrast, a visual target or a tactile target at the hand not casting the shadow constituted an 'incongruent' trial. Shadow side and target location were again totally unpredictable in each trial, thus there was no advantage for the participant to strategically orient attention towards the shadow.

3. Results

3.1. Tactile targets in personal space

RTs for correct responses above or below 2.5 standard deviations from the mean were trimmed. Data from one participant were removed due to excessively slow responses (Mean RT = 930 ms; group mean RT = 541 ms, SD = 63 ms). RT trimming resulted in the removal of less than 1% of data for the remaining participants. The Greenhouse–Geisser correction was applied to the ANOVA when necessary.

Mean RTs and percent errors for Experiment 1 are reported in Table 1 as a function of cue-target spatial congruency and SOA. RT data were then entered into a two-way repeated measures ANOVA with SOA (100, 600, 1200 or 2400 ms) and cue-target spatial congruency (congruent vs. incongruent) as factors. The ANOVA revealed a main effect of cue-target spatial congruency ($F(1,17) = 17.2$, $p = .001$, $\eta^2_p = 0.50$) caused by faster RTs in congruent ($M = 537$ ms, $SE = 15$) than incongruent trials ($M = 546$ ms, $SE = 15$; $p = .001$; see Fig. 2a). In addition, there was a significant effect of SOA ($F(3,51) = 6.8$, $\varepsilon = 0.79$, $p = .002$, $\eta^2_p = 0.29$) caused by shorter RTs at the 1200-ms SOA than all other SOAs (all ps < .02, uncorrected), and possibly reflecting a

Table 1
Mean RT (in ms) and errors (%) with standard error (*SE*) in parenthesis, for Experiments 1–4 as a function of SOA and cue-target spatial congruency.

	SOA 100 ms								SOA 600 ms								SOA 1200 ms								SOA 2400 ms							
	Congruent				Incongruent				Congruent				Incongruent				Congruent				Incongruent				Congruent				Incongruent			
	RT (ms)		Errors (%)		RT (ms)		Errors (%)		RT (ms)		Errors (%)		RT (ms)		Errors (%)		RT (ms)		Errors (%)		RT (ms)		Errors (%)		RT (ms)		Errors (%)		RT (ms)		Errors (%)	
	M	(*SE*)	*M*	(*SE*)	*M*	(*SE*)	*M*	(*SE*)	*M*	(*SE*)	*M*	(*SE*)	*M*	(*SE*)	*M*	(*SE*)	*M*	(*SE*)	*M*	(*SE*)	*M*	(*SE*)	*M*	(*SE*)	*M*	(*SE*)	*M*	(*SE*)	*M*	(*SE*)	*M*	(*SE*)
Experiment 1																																
Touch in personal space	549	(17)	1.8	(0.5)	551	(18)	2.3	(0.7)	542	(16)	2.0	(0.6)	551	(15)	2.4	(0.6)	522	(13)	1.2	(0.5)	533	(14)	1.2	(0.4)	538	(14)	1.4	(0.4)	547	(17)	1.4	(0.5)
Experiment 2																																
Vision in extra-personal space	516	(12)	1.8	(0.5)	530	(18)	2.1	(0.5)	512	(11)	1.6	(0.6)	522	(10)	1.3	(0.4)	490	(10)	0.8	(0.2)	509	(9)	1.6	(0.4)	493	(12)	1.0	(0.4)	506	(12)	2.0	(0.6)
Experiment 3																																
Touch in personal space	545	(15)	2.1	(0.6)	559	(17)	1.9	(0.9)	541	(17)	1.4	(0.4)	553	(18)	0.3	(0.2)	545	(18)	1.1	(0.4)	554	(19)	1.7	(0.5)	545	(18)	1.4	(0.6)	559	(16)	2.5	(0.6)
Vision in extra-personal space	539	(15)	0.9	(0.5)	542	(14)	1.1	(0.4)	559	(16)	1.1	(0.4)	564	(15)	1.5	(0.9)	547	(16)	1.6	(0.5)	550	(15)	0.8	(0.4)	555	(15)	0.5	(0.3)	555	(15)	0.6	(0.3)
Experiment 4																																
Touch in personal space	552	(21)	2.0	(0.5)	562	(21)	2.8	(0.7)	539	(18)	2.6	(1.0)	555	(19)	2.9	(0.8)	548	(20)	2.0	(0.8)	551	(18)	1.5	(0.5)	552	(20)	2.0	(0.7)	549	(19)	1.5	(0.5)
Vision in personal space	592	(20)	7.5	(1.1)	577	(20)	5.9	(1.2)	580	(19)	7.4	(1.2)	574	(20)	3.3	(0.6)	566	(16)	5.1	(0.8)	560	(22)	5.1	(1.1)	564	(19)	7.0	(1.1)	561	(17)	3.3	(0.4)

foreperiod-like effect (e.g., Piras & Coull, 2011). Notably, however, there was no interaction between cue-target spatial congruency and SOA ($F(3,51) = 0.6$; see Fig. 2a). A similar ANOVA on percent errors only revealed a marginally significant effect of SOA ($F(3,51) = 2.9$, $\varepsilon = 0.78$, $p = .06$, $\eta^2_p = 0.14$), again reflecting a tendency for better performance (i.e., fewer errors) at the 1200-ms SOA.

3.2. Visual targets in extra-personal space

RT trimming resulted in the removal of 1.2% of data. Mean RTs and percent errors for Experiment 2 are reported in Table 1 as a function of cue-target spatial congruency and SOA. RT data were then entered into a two-way repeated measures ANOVA with SOA (100, 600, 1200 or 2400 ms) and cue-target spatial congruency (congruent vs. incongruent) as factors.

The ANOVA revealed a main effect of cue-target spatial congruency ($F(1,17) = 12.7$, $p = .002$, $\eta^2_p = 0.43$) caused by faster RTs in congruent ($M = 503$ ms, $SE = 11$) than incongruent trials ($M = 517$ ms, $SE = 11$). In addition, there was a significant effect of SOA ($F(3,51) = 6.5$, $\varepsilon = 0.60$, $p = .006$, $\eta^2_p = 0.27$) caused by RTs becoming progressively faster as the SOA increased. As in Experiment 1, no interaction between cue-target spatial congruency and SOA ($F(3,51) = 0.5$) emerged (see Fig. 2b). A similar ANOVA on percent errors only revealed a marginally significant effect of cue-target spatial congruency ($F(1,17) = 3.7$, $p = .07$, $\eta^2_p = 0.18$), reflecting a tendency for fewer errors on congruent ($M = 1.3\%$, $SE = 0.3$) than incongruent trials ($M = 1.8\%$, $SE = 0.4$).

3.3. Tactile targets in personal space, visual targets in extra-personal space

RT trimming resulted in the removal of less than 1% of data. One participant was excluded due to excessive mistakes (11%; group average = 1.3%, SD = 0.8%). Mean RTs and percent errors for Experiment 3 are reported in Table 1 as a function of cue-target spatial congruency and SOA. RT data were then entered into a repeated-measures ANOVA with Target Type (Tactile or Visual), SOA (100, 600, 1200 or 2400 ms) and cue-target spatial congruency (congruent vs. incongruent) as factors.

The ANOVA revealed a main effect of cue-target spatial congruency ($F(1,18) = 12.7$, $p = .002$, $\eta^2_p = 0.41$) caused by faster RTs in congruent ($M = 547$ ms, $SE = 16$) than incongruent trials ($M = 555$ ms, $SE = 16$). The interaction between cue-target spatial congruency and Target Type also approached significance ($F(1,18) = 3.5$, $p = .08$, $\eta^2_p = 0.16$), revealing a tendency for larger cueing effects for tactile ($M_{congruent} = 544$ ms, $SE = 16$; $M_{incongruent} = 556$ ms, $SE = 17$; i.e., net cueing effect = 12 ms) than visual targets ($M_{congruent} = 550$ ms, $SE = 15$; $M_{incongruent} = 553$ ms, $SE = 15$; i.e., net cueing effect = 3 ms; see Fig. 2c). Finally, there was a significant interaction between Target Type and SOA ($F(3,54) = 5.9$, $\varepsilon = 0.81$, $p = .003$, $\eta^2_p = 0.25$). At the 600 ms SOA participants responded faster for tactile ($M = 547$ ms, $SE = 17$) than visual targets ($M = 561$ ms, $SE = 16$),

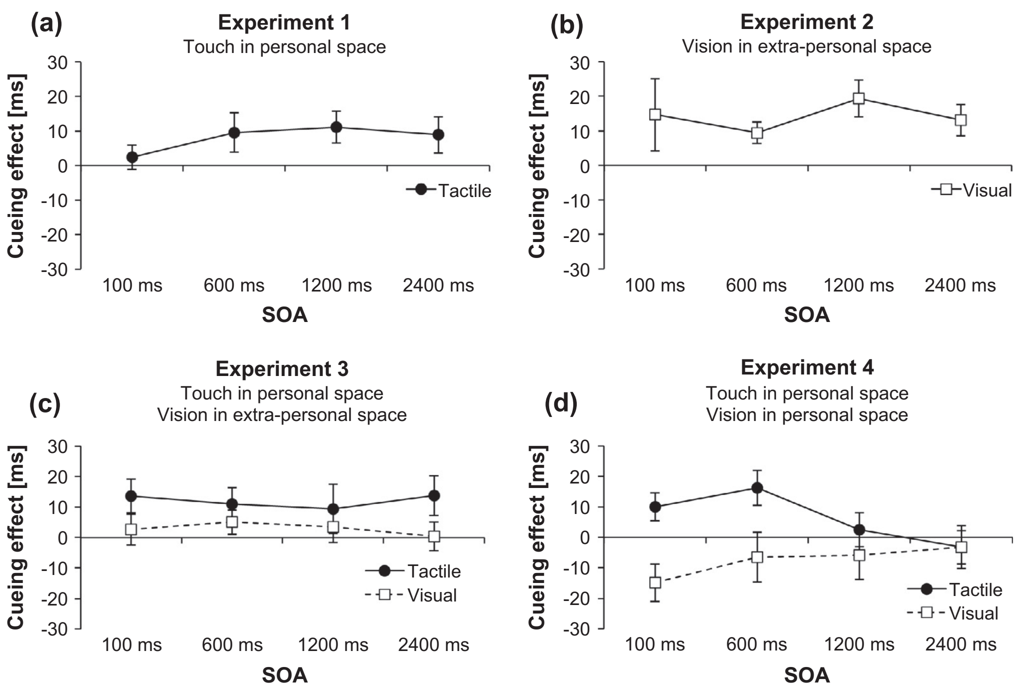

Fig. 2. Cueing effect as a function of SOA in: (a) Experiment 1 (touch in personal space); (b) Experiment 2 (vision in extra-personal space); (c) Experiment 3 (touch in personal space, vision in extra-personal space); (d) Experiment 4 (touch and vision in personal space). Error bars denote standard error of the mean.

whereas response times to vision and touch were comparable at the other SOAs. No other main effect or interaction emerged (all *F*s < 1). A similar ANOVA on percent errors only revealed a significant effect of Target Type ($F(1,18) = 10.6$, $p = .04$, $\eta^2_p = 0.37$) caused by more errors for tactile ($M = 1.6\%$, $SE = 0.2$) than visual target ($M = 1.0\%$, $SE = 0.2$).

In the attempt to obtain further evidence about the lack of shadow-driven orienting in extra-personal space, RT data were also submitted to Bayesian analyses. This approach helps disentangling which model (null vs. alternative hypothesis) is more strongly supported by the available data and is particularly helpful for dealing with the null hypothesis appropriately. The Bayesian Information Criterion (BIC) was computed following the procedure proposed by Masson (2011). This analysis showed that the posterior probability supporting the hypothesis that shadow-driven orienting was absent for visual targets was $p_{BIC}(H_0|D) = .694$. In sharp contrast, the posterior probability favouring the hypothesis that shadow-driven orienting was absent for tactile targets was $p_{BIC}(H_0|D) = .066$. Within this framing, BIC values lower than 0.50 indicate that there is more evidence for the alternative than for the null hypothesis, whereas values higher than 0.50 indicate the opposite. Following to the conventional categorization of degrees of evidence, the obtained posterior probabilities for the null hypothesis constitute "positive" evidence for the conclusion that no shadow-driven orienting occurred in extra-personal space. In contrast, the obtained posterior probabilities offer strong support to the conclusion that shadow-driven orienting occurred in personal space.

3.4. Tactile and visual targets in personal space

RT trimming resulted in the removal of 5% of data. Two participants were excluded from the analyses: one participant made excessive mistakes (12%; group average = 4%, SD = 1%), another one did not complete the experimental session. Mean RTs and percent errors for Experiment 4 are reported in Table 1 as a function of cue-target spatial congruency and SOA. RT data were entered into a two-way repeated measures ANOVA with target type (tactile or visual), SOA (100, 600, 1200 or 2400 ms) and cue-target spatial congruency (congruent vs. incongruent) as factors.

The ANOVA revealed a significant interaction between target type and cue-target spatial congruency ($F(1,16) = 9.0$, $p = .008$, $\eta^2_p = 0.36$) caused by positive cueing effects for tactile targets ($M_{congruent} = 548$ ms, $SE = 19$; $M_{incongruent} = 554$ ms, $SE = 19$; net cueing effect = 6 ms) but negative cueing effects for visual targets ($M_{congruent} = 575$ ms, $SE = 18$; $M_{incongruent} = 568$ ms, $SE = 19$; net cueing effect = −7 ms). Although Fig. 2d suggests that the difference in cueing effect between modalities was most pronounced for the shortest SOAs, the three-way interaction between cue-target spatial congruency, target type and SOA did not reach significance ($F(3,48) = 1.2$, $p = .3$, $\eta^2_p = 0.07$). Similar to Experiment 3, there was also a significant interaction between Target Type and SOA ($F(3,48) = 6.1$, $\varepsilon = 0.82$, $p = .03$, $\eta^2_p = 0.28$). Response times to visual targets were slower compared to tactile RTs at the 100 ms ($M_{vision} = 584$ ms, $SE = 20$; $M_{touch} = 557$ ms, $SE = 21$) and at the 600 ms SOAs ($M_{vision} = 577$ ms, $SE = 19$; $M_{touch} = 547$ ms, $SE = 18$). Instead, no difference emerged between vision and touch emerged at the 1200 ms ($M_{vision} = 563$ ms, $SE = 19$; $M_{touch} = 549$ ms, $SE = 19$) or 2400 ms SOAs ($M_{vision} = 562$ ms, $SE = 18$; $M_{touch} = 551$ ms, $SE = 19$). The main effect of target type ($F(1,16) = 10.0$, $p = .006$, $\eta^2_p = 0.38$) and the main effect of SOA ($F(3,48) = 3.6$, $\varepsilon = 0.68$, $p = .04$, $\eta^2_p = 0.19$) also reached significance, but subsidiary to the higher order interaction described above. No other main effect or interaction emerged (all *F*s < 1).

A similar ANOVA on percent errors only revealed a significant interaction between target type and cue-target spatial congruency ($F(1,16) = 11.0$, $p = .004$, $\eta^2_p = 0.41$), caused by a difference between congruent and incongruent trials when responding to visual targets ($M_{congruent} = 6.5\%$, $SE = 0.6\%$; $M_{incongruent} = 4.2\%$, $SE = 0.6\%$), which did not emerge for tactile targets ($M_{congruent} = 2.1\%$, $SE = 0.5\%$; $M_{incongruent} = 2.1\%$ ms, $SE = 0.3\%$). In agreement with the RT results, the net cueing effect measured for visual targets was negative (net cueing effect = −4.4%). The main effect of target type ($F(1,16) = 34.2$, $p < .0001$, $\eta^2_p = 0.69$) and the main effect of cue-target spatial congruency ($F(1,16) = 11.9$, $p = .003$, $\eta^2_p = 0.43$) also reached significance. No other main effect or interaction emerged (all *F*s < 1.8).

Bayesian analyses conducted on RT data showed that the posterior probability supporting the hypothesis that shadow-driven orienting was absent for tactile targets was $p_{BIC}(H_0|D) = .137$, thus providing evidence for the conclusion that shadow-driven orienting occurred in personal space for tactile targets. Unlike in Experiment 3, the posterior probability favouring the hypothesis that shadow-driven orienting was absent for visual targets was $p_{BIC}(H_0|D) = .226$. Although this pattern suggests that shadow-driven orienting in personal space was present also for visual targets, it is worth remembering that, however, such effect was reversed (i.e., participants responded faster on spatially incongruent with respect to spatially congruent trials).

3.5. Between-experiments comparisons

To assess whether shadow-driven orienting was sensitive to contextual variables, we statistically compared shadow-driven orienting for *tactile* targets when presented in isolation (Experiment 1) vs. intermixed with visual targets in extra-personal space (Experiment 3) or with visual targets in personal space (Experiment 4). Similarly, we compared shadow-driven orienting for *visual* targets when tested in isolation (Experiment 2) vs. intermixed with tactile targets (Experiment 3 and 4). To this purpose, RTs for correct responses were entered in separate ANOVAs with cue-target spatial congruency and Experiment as factors. The ANOVA on tactile targets revealed a significant main effect of cue-target spatial congruency ($F(1,51) = 28.9$, $p < .0001$, $\eta^2_p = 0.36$), but no interaction involving experiment ($F = 1.0$). By contrast, the ANOVA on visual targets revealed a significant interaction between cue-target spatial congruency and experiment ($F(1,51) = 10.9$, $p < .0001$,

η^2_p = 0.30). A significant shadow-driven orienting emerged when visual targets were presented in isolation (Experiment 1: $t(17) = 3.5$, $p = .003$). By contrast, it was abolished when visual targets appeared in extra-personal and were intermixed with tactile targets (Experiment 3: $t(18) = 1.1$, $p = .3$) and it became an advantage for incongruent compared to congruent targets when visual targets in personal space were intermixed with tactile targets (Experiment 4: $t(16) = 2.5$, $p = .03$).

To assess whether shadow-driven orienting for tactile targets arose early in processing we statistically compared shadow-driven orienting for tactile targets presented 100 ms after shadow onset in the three experiments. To this purpose, RTs for the 100-ms SOA condition were entered in an ANOVAs with cue-target spatial congruency and Experiment as factors. The analysis revealed a significant main effect of cue-target spatial congruency ($F(1,51) = 10.3$, $p = .002$, $\eta^2_p = 0.17$), but no interaction involving experiment ($F(2,51) = 1.5$, $p = .2$, $\eta^2_p = 0.06$). To address the presence of shadow-driven orienting for tactile targets at the 100-ms SOA more thoroughly, Bayesian analyses were conducted. The posterior probability favouring the hypothesis that shadow-driven orienting was absent was $p_{BIC}(H_0|D) = .766$ in Experiment 1, $p_{BIC}(H_0|D) = .234$ in Experiment 3, and $p_{BIC}(H_0|D) = .346$ in Experiment 4. Within this framing, the obtained posterior probabilities constitute evidence for the conclusion that shadow-driven orienting occurred at the 100-ms SOA, both in Experiment 3 and 4.

4. Discussion

The aim of the work was to study the automaticity of shadow-driven orienting for stimuli occurring both in personal space and in extra-personal space. To this purpose, we introduced two experimental manipulations, based on the notion that automatic processing both arises early (e.g., Cheal et al., 1994; Müller & Rabbitt, 1989) and it is resistant to contextual factors (e.g., Pavan et al., 2011; Ristic & Kingstone, 2005; Zbrodoff & Logan, 1986). Overall, the results of the four experiments revealed a dissociation between shadow-driven orienting for touch and visual stimuli. For tactile targets on the body, body shadows generally elicited early-rising and persistent attention shifts, irrespective of both shadow-to-target SOA and predictability of target modality. This is strong evidence supporting the notion that shadow-driven orienting is largely automatic for tactile stimuli on the body. Conversely, for visual targets, body shadows elicited an early-rising and long-lasting attention shift only when visual targets were presented in isolation. When visual and tactile targets were intermixed within the same blocks of trials – thus making target modality unpredictable – shadow-driven orienting in extra-personal space disappeared entirely (Experiment 3) or even reversed (Experiment 4). This suggests that this latter orienting phenomenon is only partially automatic, in that it appears shortly after shadow onset but it is highly sensitive to contextual manipulations.

4.1. Automatic orienting for tactile targets

Body shadows elicit consistent orienting of attention towards the body part casting them. Experiments 1, 3 and 4 revealed a significantly better spatial discrimination for tactile targets presented at the hand casting the shadow (congruent trials) over targets presented at the hand casting no shadow (incongruent trials), in full support of our previous works (Galfano & Pavani, 2005; Pavani & Galfano, 2007). In addition to this further replication, the results of the present study critically show that shadow-driven orienting in personal space was present for tactile targets only and emerged very early in processing. Because shadows conveyed no spatially predictive information as to target location, this, in turn, seems to suggest that shadow-driven orienting genuinely reflects reflexive, stimulus-driven processing, emerging quickly after shadow onset, similar to what happens with both peripheral abrupt onsets (e.g., Friesen & Kingstone, 2003; Posner & Cohen, 1984) and schematic eye gaze (e.g., Friesen & Kingstone, 1998; Galfano et al., 2012). Further support to the notion of automatic orienting to tactile targets triggered by body shadows emerged from the observation that such a phenomenon is insensitive to manipulations of contextual factors. In Experiments 3 and 4, in which target modality (tactile vs. visual) was entirely unpredictable, reliable shadow-driven orienting effects were observed for tactile targets only. Importantly, the magnitude of such effects was comparable to that measured when tactile targets were administered in isolation (albeit the effect decayed somewhat faster in Experiment 4).

This result is particularly striking when considered in the context of other signals that are known to influence orienting of attention. It is worth noting that even gaze-driven orienting, which is considered strongly automatic in many regards (e.g., Galfano et al., 2012; Kuhn & Kingstone, 2009; Law, Langton, & Logie, 2011) has been shown to be sensitive to contextual factors such as the presence of other cuing stimuli within the same block of trials (Pavan et al., 2011). The novel observation that orienting driven by body shadows is even more resistant to contextual manipulations than gaze cueing indicates that body shadows constitute a high priority stimulus for attention.

There are at least two reasons why body shadows should be a high priority visual stimulus. First, they convey information about our body in the environment both in terms of spatial layout and in terms of anticipation of contact of objects with the body. Second, they can contribute to the fundamental process of creating and maintaining the distinction between self and the outside world (and in particular others), by repeatedly priming one's own body in the environment. These relevant aspects related to body shadow processing may account for the strong automaticity of shadow-driven orienting for somatosensation and personal space. Furthermore, they provide a possible interpretation for the persistence of shadow-driven orienting at very long SOAs (see also Galfano & Pavani, 2005; Pavani & Galfano, 2007). At first sight, such a long-lasting effect may appear difficult to reconcile with a pure stimulus-driven view of shadow-driven orienting. This finding, however, may suggest that body shadows act as strong, highly prioritized primes for one's body and such priming mechanisms take over standard dynamics governing orienting of attention.

This result is important also because it indicates that the solution of the so-called 'shadow correspondence problem' (Mamassian, 2004), in which a seen cast shadow is matched with the object that casts it (in the present study, a body part), can be an almost immediate process, at least when real body shadows are used with spatio-temporal correlation with the body parts casting them (Pavani & Galfano, 2007).

4.2. Partially automatic orienting for visual targets

Unlike orienting to tactile targets, shadow-driven orienting to visual targets does not satisfy a strong definition of automaticity in that it proved sensitive to contextual manipulations. Specifically, task-irrelevant body shadows proved capable of eliciting attention shifts only to the extent that visual targets were presented in isolation (see Experiment 2). As shown in Experiment 3 and 4, when target modality became unpredictable shadow-driven orienting vanished. This pattern was further confirmed both by a between experiment ANOVA and by Bayesian analyses (see Fig. 2). This expands the previous results of Pavani and Galfano (2007) in two important ways. First, the present findings show that shadow-driven orienting can occur also for visual targets in extra-personal space at least under specific conditions (i.e., absence of other competing targets at the body). Second, the temporal dynamics underlying this effect (when present) appear largely comparable to those measured for personal space, suggesting that the dissociation between the two spaces may relate more to the triggering mechanism rather than to access to qualitatively different orienting mechanisms.

Our study of temporal dynamics of shadow-stimulus is relevant also for the literature that documented prioritized attentional processing for visual stimuli near the body. Studies of brain damaged patients showed that the neuropsychological phenomenon of visual extinction (i.e., failure to report contralesional visual stimuli, when presented together with concurrent ipsilesional ones) is less severe when the patient's hands are visible near the stimuli (di Pellegrino & Frassinetti, 2000). Similarly, detection of contralesional visual stimuli can improve in a patient with a lesion of the visual cortex, when these stimuli are placed within hand reach (Schendel & Robertson, 2004). This finding has now been extended to healthy humans, with advantages in visual processing documented in a range of perceptual (Abrams, Davoli, Du, Knapp, & Paull, 2008; Cosman & Vecera, 2010; Reed, Grubb, & Steele, 2006; Tseng & Bridgeman, 2011) and learning tasks (Davoli, Brockmole, & Goujon, 2012). Furthermore, it has been revealed even when the proximity between the hands and the visual stimuli is only an imagined posture (Davoli & Abrams, 2009). This prioritized visual processing near the hands has been interpreted in relation to multisensory coding of peripersonal space by bimodal neurons (di Pellegrino & Frassinetti, 2000), in relation to the need to process potential reach targets to a larger extent (Reed et al., 2006) and recently linked to processing occurring within the action-oriented magnocellular visual pathway (Gozli, West, & Pratt, 2012). The present findings contribute to this literature in three important ways. First, they show that even hand shadows can induce a priority processing for visual stimuli presented in extra-personal space but near the cast shadow of the hand. Second, they reveal that a cueing effect for visual stimuli near the hands can emerge even when the hand-shadow proximity is manipulated on a trial-by-trial basis (note that all previous studies changed hand proximity to visual targets across blocks). Third, our novel findings show that this prioritized visual processing can occur at very short latencies, at least when targets are presented in extra-personal space only (Experiment 2).

So why did capture of attention by body-shadows became less effective, and only partially automatic, when a contextual manipulation was introduced (i.e., tactile and visual targets were intermixed in Experiment 3 and 4)? One intriguing possibility is that body shadows act as an extension of the body, as originally proposed by Pavani and Castiello (2004), only when the representation of the actual boundaries of the physical body are not competing directly with the body shadow. In other words, body shadows can be perceived as veridical extensions of our own body as long as the actual body extension is not made evident by the task or by the incoming stimuli. According to this speculation when visual stimuli were the only targets, body representation could extend to include the hand shadow stretched towards the visual stimuli. As such, visual stimuli were encoded as near to the body, and prioritized. By contrast, when visual and tactile stimuli competed, the boundaries of the body 'shrunk' to the actual physical body resulting in facilitation only for the tactile targets on the body. Interestingly, this selectivity for somatosensory stimuli when tactile and visual targets are intermixed persists even when visual stimuli are also delivered in personal space (Experiment 4). This provides further evidence that shadow orienting can favour a purely somatosensory representation of the body, instead of a multisensory representation that includes also visual stimuli near the body (see also Pavani & Galfano, 2007).

Finally, one unexpected finding emerged from Experiment 4, in which visual and tactile targets were both delivered at the hands. While responses to tactile targets were faster at the hand casting the shadow compared to the opposite hand, the reversed pattern emerged for visual stimuli. This led to a significantly negative cueing effect for visual targets. One interpretation for this unexpected finding relates to the notion of switching attention between sensory modalities. Turatto and colleagues (Turatto, Benso, Galfano, & Umiltà, 2002; Turatto, Galfano, Bridgeman, & Umiltà, 2004) showed that when two consecutive stimuli (S1 and S2) are delivered in same or different sensory modalities, responses to S2 are slower when S1 is delivered in a different sensory modality (crossmodal trial) compared to when S1 is delivered in the same sensory modality as S2 (ipsimodal trial). By extending this notion to our findings, we can speculate that body shadows trigger an attention shift to touch at the hand casting the shadow. In turn, responding to a visual target occurring at the same hand require to switch attention between modalities (i.e., from touch to vision), leading to slower responses. While this speculation clearly deserves empirical testing, it may constitute another indication that body-shadows bias spatial selective attention specifically for the tactile modality.

5. Conclusions

On the grounds of these results, body shadows can be interpreted as powerful cues that summon attention to somatosensation at the corresponding body part in a highly stimulus-driven fashion, despite being spatially uninformative and irrelevant to the task at hand. This interpretation is favoured by the observation that this effect takes place early after shadow onset and is maintained for an incredibly long time. Importantly, the observation of shadow-driven orienting effects with a 100-ms SOA shows that self attribution of body shadows takes place very quickly. Furthermore, shadow-driven was resistant to contextual manipulations with tactile targets, but not with visual targets. Such dissociation between touch and vision casts evidence in favour of an interpretation of shadow-driven orienting as a multi-faceted phenomenon. On the one hand, shadow-driven orienting to touch could be interpreted as a genuinely stimulus-driven phenomenon, because it is relatively impervious to manipulations of the experimental setting (cue-to-target SOA) and task requirements (tactile stimuli presented in isolation or intermixed with visual targets). On the other hand, shadow-driven orienting to vision is sensitive to experimental settings and can be better interpreted as an instance of mixed orienting effect, whose stimulus-driven nature cannot said to be pure.

Acknowledgments

Part of the results reported here were presented at the European Conference on Visual Perception, Arezzo, Italy, 2007. We are grateful to two anonymous reviewers for their comments on a previous version of the manuscript. The authors would like to thank Mr. Damiano Zenari for help in data collection. This work has been realized also thanks to the support from the Fondazione Cassa di Risparmio di Trento e Rovereto.

References

Abrams, R. A., Davoli, C. C., Du, F., Knapp, W. H., 3rd, & Paull, D. (2008). Altered vision near the hands. *Cognition, 107*, 1035–1047. http://dx.doi.org/10.1016/j.cognition.2007.09.006.

Bargh, J. A., & Ferguson, M. J. (2000). Beyond behaviorism: On the automaticity of higher mental processes. *Psychological Bulletin, 126*, 925–945. http://dx.doi.org/10.1037/0033-2909.126.6.925.

Bonfiglioli, C., Pavani, F., & Castiello, U. (2004). Differential effects of cast shadows on perception and action. *Perception, 33*, 1291–1304. http://dx.doi.org/10.1068/p5325.

Casati, R. (2003). *The shadow club: The greatest mystery in the universe–shadows–and the thinkers who unlocked their secrets*. New York, USA: Knopf.

Castiello, U. (2001). Implicit processing of shadows. *Vision Research, 41*, 2305–2309. http://dx.doi.org/10.1016/s0042-6989(01)00141-9.

Cheal, M.-L., Lyon, D. R., & Gottlob, L. R. (1994). A framework for understanding the allocation of attention in location-precued discrimination. *Quarterly Journal of Experimental Psychology, 47A*, 699–739. http://dx.doi.org/10.1080/14640749408401134.

Cosman, J. D., & Vecera, S. P. (2010). Attention affects visual perceptual processing near the hand. *Psychological Science, 21*, 1254–1258. http://dx.doi.org/10.1177/0956797610380697.

Davoli, C. C., & Abrams, R. A. (2009). Reaching out with the imagination. *Psychological Science, 20*, 293–295. http://dx.doi.org/10.1111/j.1467-9280.2009.02293.x.

Davoli, C. C., Brockmole, J. R., & Goujon, A. (2012). A bias to detail: How hand position modulates visual learning and visual memory. *Memory and Cognition, 40*, 352–359. http://dx.doi.org/10.3758/s13421-011-0147-3.

di Pellegrino, G., & Frassinetti, F. (2000). Direct evidence from parietal extinction of enhancement of visual attention near a visible hand. *Current Biology, 10*, 1475–1477. http://dx.doi.org/10.1016/S0960-9822(00)00809-5.

Downing, P. E., Jiang, J., Shuman, M., & Kanwisher, N. (2001). A cortical area selective for visual processing of the human body. *Science, 293*, 2470–2473. http://dx.doi.org/10.1126/science.1063414.

Driver, J., Davis, G., Ricciardelli, P., Kidd, P., Maxwell, E., & Baron-Cohen, S. (1999). Gaze perception triggers reflexive visuo-spatial orienting. *Visual Cognition, 6*, 509–540. http://dx.doi.org/10.1080/135062899394920.

Elder, J. H., Trithart, S., Pintilie, G., & MacLean, D. (2004). Rapid processing of cast and attached shadows. *Perception, 33*, 1319–1338. http://dx.doi.org/10.1068/p5323.

Friesen, C. K., & Kingstone, A. (1998). The eyes have it! Reflexive orienting is triggered by nonpredictive cue gaze. *Psychonomic Bulletin & Review, 5*, 490–495. http://dx.doi.org/10.3758/BF03208827.

Friesen, C. K., & Kingstone, A. (2003). Abrupt onsets and gaze direction cues trigger independent reflexive attentional effects. *Cognition, 87*, B1–B10. http://dx.doi.org/10.1016/S0010-0277(02)00181-6.

Frischen, A., & Tipper, S. P. (2004). Orienting attention via observed gaze shift evokes longer term inhibitory effects: Implications for social interactions, attention, and memory. *Journal of Experimental Psychology: General, 133*, 516–533. http://dx.doi.org/10.1037/0096-3445.133.4.516.

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

Galfano, G., & Pavani, F. (2005). Long-lasting capture of tactile attention by body shadows. *Experimental Brain Research, 166*, 518–527. http://dx.doi.org/10.1007/s00221-005-2392-9.

Galfano, G., Sarlo, M., Sassi, F., Munafò, M., Fuentes, L. J., & Umiltà, C. (2011). Reorienting of spatial attention in gaze cuing is reflected in N2pc. *Social Neuroscience, 6*, 257–269. http://dx.doi.org/10.1080/17470919.2010.515722.

Gozli, D. G., West, G. L., & Pratt, J. (2012). Hand position alters vision by biasing processing through different visual pathways. *Cognition, 124*, 244–250. http://dx.doi.org/10.1016/j.cognition.2012.04.008.

Igarashi, Y., Kitagawa, N., Spence, C., & Ichihara, S. (2007). Assessing the influence of schematic drawings of body parts on tactile discrimination performance using the crossmodal congruency task. *Acta Psychologica, 124*, 190–208. http://dx.doi.org/10.1016/j.actpsy.2006.03.004.

Imura, T., Yamaguchi, M. K., Kanazawa, S., Shirai, N., Otsuka, Y., Tomonaga, M., et al (2006). Perception of motion trajectory of object from the moving cast shadow in infants. *Vision Research, 46*, 652–657. http://dx.doi.org/10.1016/j.visres.2005.07.028.

Kersten, D., Mamassian, P., & Knill, D. C. (1997). Moving cast shadows induce apparent motion in depth. *Perception, 26*, 171–192. http://dx.doi.org/10.1068/p260171.

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

Law, A. S., Langton, S. R. H., & Logie, R. H. (2011). Assessing the impact of verbal and visuospatial working memory load on eye-gaze cueing. *Visual Cognition, 18*, 1420–1438. http://dx.doi.org/10.1080/13506285.2010.496579.

Mamassian, P. (2004). Impossible shadows and the shadow correspondence problem. *Perception, 33*, 1279–1290. http://dx.doi.org/10.1068/p5280.
Mamassian, P., Knill, D. C., & Kersten, D. (1998). The perception of cast shadows. *Trends in Cognitive Sciences, 2*, 288–295. http://dx.doi.org/10.1016/S1364-6613(98)01204-2.
Mascalzoni, E., Regolin, L., & Vallortigara, G. (2009). Mom's shadow: Structure-from-motion in newly-hatched chicks as revealed by an imprinting procedure. *Animal Cognition, 12*, 389–400. http://dx.doi.org/10.1007/s10071-008-0198-4.
Masson, M. E. J. (2011). A tutorial on a practical Bayesian alternative to null-hypothesis significance testing. *Behavior Research Methods, 43*, 679–690. http://dx.doi.org/10.3758/s13428-010-0049-5.
Moors, A., & De Houwer, J. (2006). Automaticity: A theoretical and conceptual analysis. *Psychological Bulletin, 132*, 297–326. http://dx.doi.org/10.1037/0033-2909.132.2.297.
Müller, H. J., & Rabbitt, P. M. A. (1989). Reflexive and voluntary orienting of visual attention: Time course of activation and resistance to suppression. *Journal of Experimental Psychology: Human Perception and Performance, 15*, 315–330. http://dx.doi.org/10.1037/0096-1523.15.2.315.
Norman, J. F., Dawson, T. E., & Raines, S. R. (2000). The perception and recognition of natural object shape from deforming and static shadows. *Perception, 29*, 135–148. http://dx.doi.org/10.1068/p2994.
Pasqualotto, A., Finucane, C. M., & Newell, F. N. (2013). Ambient visual information confers a context-specific, long-term benefit on memory for haptic scenes. *Cognition, 128*, 363–379. http://dx.doi.org/10.1016/j.cognition.2013.04.011.
Pavan, G., Dalmaso, M., Galfano, G., & Castelli, L. (2011). Racial group membership is associated to gaze-mediated orienting in Italy. *PLoS One, 6*, e25608. http://dx.doi.org/10.1371/journal.pone.0025608.
Pavani, F., & Castiello, U. (2004). Binding personal and extrapersonal space through body shadows. *Nature Neuroscience, 7*, 13–14. http://dx.doi.org/10.1038/nn1167.
Pavani, F., & Galfano, G. (2007). Self-attributed body-shadows modulate tactile attention. *Cognition, 104*, 73–88. http://dx.doi.org/10.1016/j.cognition.2006.05.007.
Pavani, F., Spence, C., & Driver, J. (2000). Visual capture of touch: Out-of-the-body experiences with rubber gloves. *Psychological Science, 11*, 353–359. http://dx.doi.org/10.1111/1467-9280.00270.
Piras, F., & Coull, J. T. (2011). Implicit, predictive timing draws upon the same scalar representation of time as explicit timing. *PLoS One, 6*, e18203. http://dx.doi.org/10.1371/journal.pone.0018203.
Posner, M. I., & Cohen, Y. (1984). Components of visual orienting. In H. Bouma & D. G. Bouwhuis (Eds.), *Attention and performance X* (pp. 531–556). Hillsdale, NJ: Erlbaum.
Pourtois, G., Peelen, M. V., Spinelli, L., Seeck, M., & Vuilleumier, P. (2007). Direct intracranial recording of body-selective responses in human extrastriate visual cortex. *Neuropsychologia, 45*, 2621–2625. http://dx.doi.org/10.1016/j.neuropsychologia.2007.04.005.
Reed, C. L., Grubb, J. D., & Steele, C. (2006). Hands up: Attentional prioritization of space near the hand. *Journal of Experimental Psychology: Human Perception and Performance, 32*, 166–177. http://dx.doi.org/10.1037/0096-1523.32.1.166.
Rensink, R. A., & Cavanagh, P. (2004). The influence of cast shadows on visual search. *Perception, 33*, 1339–1358. http://dx.doi.org/10.1068/p5322.
Ristic, J., & Kingstone, A. (2005). Taking control of reflexive social attention. *Cognition, 94*, B55–B65. http://dx.doi.org/10.1016/j.cognition.2004.04.005.
Ro, T., Friggel, A., & Lavie, N. (2007). Attentional biases for faces and body parts. *Visual Cognition, 15*, 322–348. http://dx.doi.org/10.1080/13506280600590434.
Schendel, K., & Robertson, L. C. (2004). Reaching out to see: Arm position can attenuate human visual loss. *Journal of Cognitive Neuroscience, 16*, 935–943. http://dx.doi.org/10.1162/0898929041502698.
Tseng, P., & Bridgeman, B. (2011). Improved change detection with nearby hands. *Experimental Brain Research, 209*, 257–269. http://dx.doi.org/10.1007/s00221-011-2544-z.
Turatto, M., Benso, F., Galfano, G., & Umiltà, C. (2002). Nonspatial attentional shifts between audition and vision. *Journal of Experimental Psychology: Human Perception and Performance, 28*, 628–639. http://dx.doi.org/10.1037//0096-1523.28.3.628.
Turatto, M., Galfano, G., Bridgeman, B., & Umiltà, C. (2004). Space-independent modality-driven attentional capture in auditory, tactile and visual systems. *Experimental Brain Research, 155*, 301–310. http://dx.doi.org/10.1007/s00221-003-1724-x.
Urgesi, C., Berlucchi, G., & Aglioti, S. M. (2004). Magnetic stimulation of extrastriate body area impairs visual processing of nonfacial body parts. *Current Biology, 14*, 2130–2134. http://dx.doi.org/10.1016/j.cub.2004.11.031.
Yonas, A., & Granrud, C. E. (2006). Infants' perception of depth from cast shadows. *Perception and Psychophysics, 68*, 154–160. http://dx.doi.org/10.3758/BF03193665.
Zbrodoff, N. J., & Logan, G. D. (1986). On the autonomy of mental processes: A case study of arithmetic. *Journal of Experimental Psychology: General, 115*, 118–130. http://dx.doi.org/10.1037/0096-3445.115.2.118.