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A new look at sensorimotor aspects in approach/avoidance tendencies: The role of visual whole-body movement information☆

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ABSTRACT

Because approach/avoidance is a crucial response to environmental stimuli, this type of action should have left its trace on our sensorimotor system. Recent work, however, downplayed the role of sensorimotor information in producing approach/avoidance compatibility effects (i.e., faster response times to approach positive stimuli and avoid negative stimuli, than the reverse). We suggest that this is likely due to an overemphasis of the role of motor aspects of arm movement in these effects. The goal of this research is therefore to reevaluate the role of sensorimotor information in the production of compatibility effects by suggesting that large and replicable effects can be observed when the task simulates the visual information that comes with whole-body movements. In line with this idea, we present six experiments showing that such a task (the Visual Approach/Avoidance by the Self Task; VAAST) can produce large and replicable compatibility effects. Importantly, these experiments also test the core aspects producing these effects. These experiments reassert the role of sensorimotor information in the production of approach/avoidance compatibility effects. This entails, however, focusing on the visual information associated with whole-body movements instead of motor aspects associated with arm movements.

One of the primary and most important behavioral response toward a stimulus is whether it should be approached or avoided. Although approach/avoidance tendencies were first implemented with tasks anchored in sensorimotor experience (i.e., arm muscles), questions are now raised about the ambiguity of their interpretation (e.g., is arm flexion an approach or an avoidance movement?), but also sometimes their lack of replicability. This state of affairs led contemporary research to downplay the involvement of sensorimotor aspects in the implementation and measurement of approach/avoidance tendencies. In this work, we intend to reassess this involvement by focusing on a different approach/avoidance experience—movements of the whole-self instead of arm movements—and a different sensorimotor modality—the visual modality instead of the motor modality. Accordingly, we argue that an approach/avoidance task simulating the visual aspects of approach/avoidance by the whole-self (i.e., walking and/or chest movements forward vs. backward) should produce strong and highly replicable approach/avoidance compatibility effects. We test this idea across six experiments.

1. Issues regarding sensorimotor approach/avoidance tasks

Let us first delineate a distinction between what one could label "sensorimotor" and "non-sensorimotor" approach/avoidance tasks. The first class refers to tasks supposedly relying on sensorimotor stimulations associated with approach/avoidance. A typical example is the joystick task in which participants perform arm flexions and extensions (e.g., Rinck & Becker, 2007). The second class refers to symbolic tasks that are not supposed to rely on sensorimotor stimulations typical of approach/avoidance, but rather on more symbolic approach/avoidance actions. An example is the manikin task in which participants move a schematic character toward or away from the stimuli (e.g., De Houwer, Crombez, Baeyens, & Hermans, 2001).

As mentioned above, approach/avoidance has first been studied by relying on sensorimotor tasks. In a first experiment of this kind, Solarz (1960) showed that individuals were faster to bring closer a card with a positive word and to push away a card with a negative word

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(compatible condition) rather than the reverse (incompatible condition). This approach/avoidance compatibility effect (i.e., difference in response times between the incompatible and the compatible condition) has been replicated across different computerized tasks, many of them relying on the sensorimotor aspects associated with arm flexion/extension. For instance, these tasks relied heavily on the motor modality involved in pulling/pushing a lever or a joystick (e.g., Chen & Bargh, 1999; Markman & Brendl, 2005; Rinck & Becker, 2007; Rotteveel & Phaf, 2004; Seibt, Neumann, Nussinson, & Strack, 2008), pushing buttons on a modified keyboard (Alexopoulos & Ric, 2007; Paladino & Castelli, 2008; Vaes, Paladino, Castelli, Leyens, & Giovanazzi, 2003) or pushing/releasing on a button box (Wentura, Rothermund, & Bak, 2000). Recently, however, several concerns have been raised about the necessity of sensorimotor aspects in reactivating approach/avoidance tendencies.

First, when focusing on the motor modality of arm movements, interpreting these movements is ambiguous because arm flexions can both represent approach (bringing something closer to us) or avoidance (withdrawing our hand from something) and arm extensions can both represent approach or avoidance (reaching something or pushing something away; van Dantzig, Pecher, & Zwaan, 2008). This explains that while numerous studies found a compatibility effect where approach was presumably associated with arm flexion and avoidance associated with arm extension (Alexopoulos & Ric, 2007; Chen & Bargh, 1999; Rinck & Becker, 2007; Rotteveel & Phaf, 2004), other studies found the opposite (Lavender & Hommel, 2007; Markman & Brendl, 2005; Paladino & Castelli, 2008; Seibt et al., 2008; Vaes et al., 2003). Importantly, this reversal could not be explained simply by the use of different paradigms (e.g., modified keyboard vs. joystick), because it sometimes happened even within the same task (i.e., a modified keyboard task, Alexopoulos & Ric, 2007 vs. Paladino & Castelli, 2008 or the joystick task, Seibt et al., 2008; van Dantzig, Zeelenberg, & Pecher, 2009).

Second, the compatibility effects produced with sensorimotor approach/avoidance tasks sometimes failed to replicate. For instance, Rotteveel et al. (2015) reported a Bayesian analysis showing more support for the null hypothesis than for the existence of a compatibility effect when replicating Chen and Bargh's (1999) experiments. Along the same line, while using clearly valenced stimuli, our research team also failed to obtain a compatibility effect with a joystick (e.g., Rinck & Becker, 2007), a modified keyboard (e.g., Paladino & Castelli, 2008), and a button box (e.g., Wentura et al., 2000; information regarding these experiments is presented in the supplementary material section). Finally, in their line of research comparing the joystick task with the manikin task, Krieglmeyer and Deutsch (2010) often failed to find a significant effect with the joystick task (more often when there was no visual feedback). Interestingly, these authors also found that a non-sensorimotor task (the manikin task) produced larger compatibility effects than a sensorimotor one (the joystick task).

These two types of concerns raise at least two possibilities: either sensorimotor information is not critical in producing approach/avoidance compatibility effects or maybe the sensorimotor information that is most often implemented in the literature (i.e., a flexion/extension of the arm) was not the most relevant one. To settle between them, one should ponder two inter-related questions: 1) what is the most prototypical (i.e., the most representative in memory traces) approach/avoidance experience (i.e., arm movements or a movement of the whole-self)? And, when considering the most prototypical experience, 2) what is the most relevant sensorimotor modality involved (i.e., the motor or visual one)? Answering these two questions will lead us to argue that the most prototypical approach/avoidance experience is a movement of the whole-self and that it should be grounded in the visual modality.

2. Identifying the most relevant sensorimotor information

There are two main reasons to argue that the most prototypical experience of approach/avoidance involves movements of the whole-self/body instead of arm movements. The first reason relates to the level of ambiguity developed earlier. With arm movements, a flexion can represent approach (e.g., bringing a cake closer) but also avoidance (e.g., withdrawing one's hand from a snake), the same being true for extension. In contrast, this level of ambiguity is very low for movements of the whole-self because, almost by definition, moving forward and backward always means approach and avoidance, respectively (Kozlik, Neumann, & Lozo, 2015; Krieglmeyer & Deutsch, 2010; Stins et al., 2011; "almost" because there are exceptions, for instance, when an obstacle first needs to be bypassed; Krieglmeyer, De Houwer, & Deutsch, 2011). The second reason relates to an intrinsic asymmetry between movements of the self and arm movements. Indeed, one can generally walk toward or away from a stimulus that can be brought closer or pushed away (e.g., a cake), but not all stimuli that can be walked toward or away from can be brought closer or pushed away (e.g., a car). Overall, movements of the self are less ambiguous and do not present the limitations that come with arm movements.

The other question concerns the type of sensorimotor modality that should be the most prevalent, and therefore important to rely on, to represent whole-body movements. Inherently, the motor experience associated with a movement of the self should be the one that comes with physically moving toward or away from a stimulus, that is, muscular stimulations needed for forward/backward walking (e.g., Stins et al., 2011) or for chest movements. However, given its general dominance over other sensory modalities (e.g., Nørretranders, 1998; Posner, Nissen, & Klein, 1976), the visual experience associated with movements of the self could be more prevalent than the muscular stimulations. Somewhat related to the idea of how critical the visual information can be, Rinck and Becker (2007) showed, while relying on an arm-movement paradigm, that visual overrides motor approach/avoidance information when they conflict. Their experiment, however, simulated the visual information associated with arm movements, namely changes in visual angles for the stimulus only (i.e., what happens perceptively when moving an object toward or away from us). Critically for our concerns, the visual information that comes with moving the whole-self should also involve changes in visual angles for the surrounding environment (e.g., the walls, the ceiling, the floor; Proffitt & Linkenauger, 2013).

For all these reasons, we believe a task simulating the visual aspects of the wholeself moving toward or away from the stimulus should produce strong and replicable approach/avoidance compatibility effects. A first set of previous studies, that mostly relied on the joystick task (e.g., Rinck & Becker, 2007), did simulate visual aspects, but those coming with actions on the stimulus instead of those coming with movements of the whole-self. A second set of studies implemented actual movements of the whole-self, but as a manipulation and not as a measure (e.g., Fayant, Muller, Nurra, Alexopoulos, & Palluel-Germain, 2011; Koch, Holland, Hengstler, & van Knippenberg, 2009). Finally, a last set of studies relied on actual (not simulated) movements of the whole-self as a measure of approach/avoidance (e.g., Ly, Huys, Stins, Roelofs, & Cools, 2014; Stins et al., 2011), but those actual movements come with measurement complexities and make it difficult to isolate the role of visual and motor aspects (see the General Discussion). All these things considered, to the best of our knowledge, until now no experiment implemented a measure of approach/avoidance simulating the visual aspects of moving the whole-self toward or away from the stimuli. This is precisely what we did with the newly developed Visual Approach/Avoidance by the Self Task (VAAST). Using a visual interactive scene, this task provides multiple visual cues (of both stimuli and environment) giving the impression that the whole-self moves toward or away from stimuli. If our reasoning is correct, such a task simulating the two key features we identified (movement of the self through the visual modality) should produce strong and replicable compatibility effects. Accordingly, we tested this idea across six experiments.

In Experiment 1, we tested this task for the first time, but also compared it to the manikin task. We did so for two reasons: Because the latter is a non-sensorimotor task and because it produced a replicable compatibility effect, larger than the one found with the joystick task (Krieglmeyer & Deutsch, 2010). In Experiment 2, we tested whether, as we contend, simulating a movement of the self is indeed critical by comparing such a condition with a condition visually simulating a movement of the stimulus (i.e., what is simulated in arm movements task). In the next three experiments, we tested whether large and replicable compatibility effects in the VAAST could emerge: in the absence of an arm flexion/extension motor compatibility (Experiment 3), with a minimal approach/avoidance movement (Experiment 4), and when stimuli are not explicitly processed (Experiment 5). Finally, we tested whether the compatibility effect in the VAAST depends on the approach/avoidance framing of the task (in the instructions and response labels)—we believe it should not—and whether the compatibility effect in the VAAST depends on the visual feedback—we believe it should. Because we did not want to rely on the null hypothesis for this last question (expecting no effect without visual feedback), we tested these last two questions in a three-condition design in which we compared the regular VAAST with two conditions: one without an approach/avoidance framing and one without visual feedback (Experiment 6).

3. Sample size, data preparation, and analytical strategy

To estimate the required sample size for sufficient power (80%) in Experiment 1 ($N = 48$), we relied on Krieglmeyer and Deutsch's effect size (2010; $d = 0.95$ for a regular ANOVA) because the goal and design of their experiment were the same as ours (comparing two tasks in a within-participants design). In Experiment 2, because we relied on the same design as in Experiment 1, we targeted the same number of participants, but ended up with a few more ($N = 56$). In Experiments 3 and 5, even though our goal was only to test a compatibility effect, we relied on larger samples, because in the former we needed to control for handedness ($N = 59$) and, in the latter, we relied on highly degraded presentation of word stimuli ($N = 67$). In Experiment 4, our goal was only to test a compatibility effect, so we recruited fewer participants ($N = 35$). Finally, because in Experiment 6 we used a between-participants design, we aimed for at least 50 participants in each condition ($N = 157$ for three conditions). In all the experiments, except Experiments 1 and 5, we used two questions asking participants about their ability in French language (one asking if French was their native language and, if it was not, a second one asking about their skills). All the participants reported having the expected skills. We only excluded four participants (in Experiment 2) because they did not answer these questions.

Because response time (RT) treatment involves many degrees of freedom in how to handle the data and because it may threaten the robustness of the findings, we used a priori filters and transformations established before data analysis, but we also report analyses with other filters and transformations as supplementary material. Accordingly, we removed incorrect trials (i.e., from 2.10% to 6.30% of the trials for the VAAST and the alternative conditions developed from this task—as the action-on-the-stimulus condition in Experiment 2 and the no approach/avoidance mention and no visual flow conditions in Experiment 6—across our experiments and 3.77% of the trials for the manikin task used in Experiment 1), as well as RTs faster than 350 ms and exceeding 1500 ms (i.e., from 2.07% to 3.72% of the trials for the VAAST and 3.61% of the trials for the manikin task used in Experiment 1) and to normalize their distribution, we transformed RTs using an inverse function (Ratcliff, 1993).

In all our experiments, we relied on mixed-model analyses to be able to use both participants and stimuli as random variables, which maximizes the robustness and the generalizability of the findings compared to traditional analyses of variance (ANOVA; Judd, Westfall, & Kenny, 2012; Westfall, Kenny, & Judd, 2014). Accordingly, for each experiment, we estimated a model with compatibility (crossed with the relevant condition and/or control depending on the design) as a fixed-effect and we estimated the related relevant random intercepts and slopes for participants, stimuli, and their interaction. In all the results sections, we report the fixed effects but not the random effects, because these random effects were outside the focus of the current contribution (see the supplementary material for more details about random effects). Given that there is yet no consensual effect size measure for mixed-models, we calculated effect sizes (dz) with regular ANOVAs for the by-participants and the by-stimuli analyses. Being particularly interested in the robustness of our findings, we computed the rate of participants and stimuli for which the compatibility effect was in the expected direction. These findings are displayed in Table 2. For the sake of simplicity, we present all the analyses in terms of compatibility effects, but these effects are in fact interactions between movement direction and valence. Because they are also informative, we report a table (Table 3) presenting all the means and the valence simple effects within each movement condition.

Table 1 presents the designs of all the experiments. The second column shows that in all these experiments, we had a within-participant compatibility manipulation. Only Experiment 5 differed in having compatible and incompatible trials manipulated within-block, while in all the other experiments we relied on a block design. The third column shows that we compared different tasks in Experiments 1 and 2 (within-participants) and Experiment 6 (between-participants). The fourth column shows controlled variables (manipulated between-participants). For instance, in all the experiments but Experiment 5, we counterbalanced compatibility block order. It is worth mentioning that when counterbalancing compatibility block order (in Experiments 1, 2,

Table 1
Designs of all the experiments.

Exp.	Compatibility	Task comparison	Between-participants control variables	Within-participants control variables
Exp. 1	Block type: comp. vs inc.	Task: VAAST vs Manikin Task	**Block order: comp. first vs inc. first** **Block order: VAAST first vs Manikin task first**	–
Exp. 2	Block type: comp. vs inc.	Task: whole-body-action vs action-on-the-stimulus	**Block order: comp. first vs inc. first** **Task order: whole-body-action first vs action-on-the-stimulus first**	–
Exp. 3	Block type: comp. vs inc.	–	**Block order: comp. first vs inc. first** **Key mapping order: app.-on-the-left first vs app.-on-the-right first** **Handedness: right-handed vs left-handed**	Key mapping: app.-on-the-left vs app.-on-the-right
Exp. 4	Block type: comp. vs inc.	–	**Block order: comp. first vs inc. first**	–
Exp. 5	Trial type*: comp. vs inc.	–	**Instructions: app. upper case vs avoid upper case**	–
Exp. 6	Block type: comp. vs inc.	**Task: VAAST, no app./avoid. mentions, no visual flow**	**Block order: comp. first vs inc. first**	–

Note. Bolded cells are between-participants variables. * "Trial type" means that in this experiment compatible and incompatible trials appeared within the same block. comp. = compatible; inc. = incompatible; app. = approach; avoid. = avoidance.

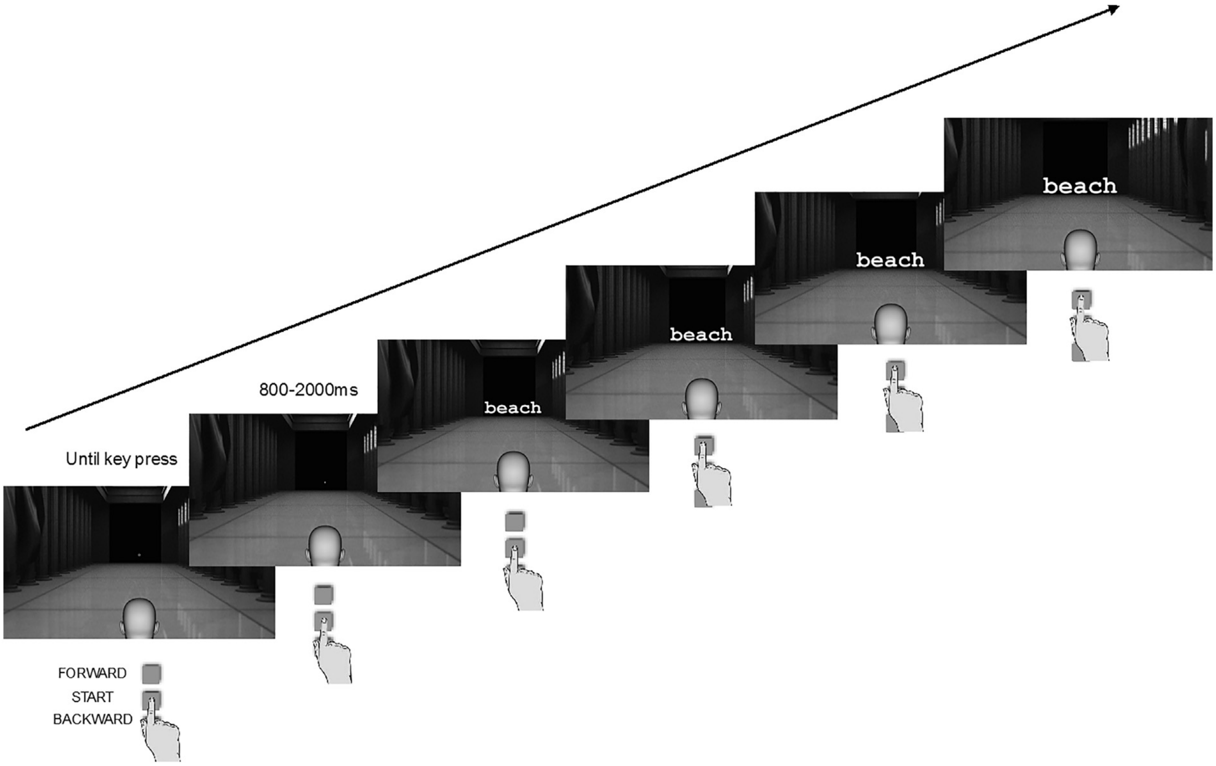

Fig. 1. Time course of a compatible trial in the VAAST.

and 3) in two conditions (i.e., the task and key mapping respectively for Experiments 1, 2, and 3) we kept the same order for a specific participant (e.g., in Experiment 1, if a participant performed the compatibility block first for the VAAST, the same was true for the manikin task). The fifth column shows that in Experiment 3, we had a within-participants control variable (i.e., the left key for approach and the right key for avoidance, or vice versa). Because the control variables never moderated any of our effects (from $F[1, 32.82] = 3.98$, $p = .054$[1], to $F[1, 54.56] = 0.07$, $p = .93$ for block order; from $F[1, 46.31] = 0.56$, $p = .46$, to $F[1, 46.03] = 0.08$, $p = .78$, for task order; $F[1, 56.64] = 1.91$, $p = .17$ for key mapping order; $F[1, 3131.25] = 0.01$, $p = .63$ for the instruction), we excluded them from the analyses and in the results sections, we will only mention the key variables for the sake of simplicity. Finally, let us mention that for all these studies, we report all measures, manipulations, and exclusions.

4. Experiment 1

The goal of Experiment 1 was twofold. First, we wanted to test whether a sensorimotor approach/avoidance task like the VAAST (i.e., relying on the visual cues associated with moving forward or backward) was able to produce a strong and robust compatibility effect. Second, we wanted to contrast this sensorimotor task with the manikin task, because it is a non-sensorimotor task and one that is known to produce larger compatibility effects than the joystick task (Krieglmeyer & Deutsch, 2010).

4.1. Method

4.1.1. Participants and design

Forty-eight students ($M_{age} = 22.07$, $SD_{age} = 6.46$, 45 females) took part in exchange for 10 euros (approximately 12.82 dollars). In this experiment, we used a 2 (compatibility: compatible vs. incompatible) × 2 (task: VAAST vs. manikin task) within-participants design. For both tasks, participants went through a compatible block (i.e., approaching positive words and avoiding negative words) and an incompatible block (i.e., approaching negative words and avoiding positive words). Each of the 16 words (8 positive and 8 negative words) was randomly presented 4 times within each block of the two tasks, so that each block comprises 64 trials. Before each block, participants performed a training phase consisting of 20 trials using 4 words that were not presented in the main experiment.

4.1.2. Procedure

For both tasks, participants responded with a button box by using the index finger of their dominant hand. Three adjacent buttons were used: one middle button to start each trial and two external buttons to perform the categorization task. The middle button was always labeled “start”, while the end buttons were labeled “move forward” vs. “move backward” for the VAAST and “left” vs. “right” for the manikin task. This difference in labels was unavoidable because, in the manikin task, a “left” button, for instance, could either translate into approach or avoidance depending on the manikin starting position (see the description below). In line with these instructions, the button box was placed such that the buttons were lined up vertically in front of the participants for the VAAST, while they were lined up horizontally for the manikin task (in Experiment 3, we show that none of the response mode features are critical for the compatibility effect in the VAAST).

4.1.3. The VAAST

First, to conform to the visual stimulation that comes with movements of the self, we used a background giving an impression of depth and we also displayed the back of the head of a character as found in some video games (Fig. 1; as we will see in Experiment 4 and in the pilot study presented in Footnote 3, we found a similar effect size without this character). When participants pressed the start button, a white circle displayed in the center of the screen was replaced by a fixation cross (random duration of 800–2000 ms), followed by a target

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[1] This effect was found in Experiment 4. Keeping this factor in the analyses does not impact the significance of the results.

word (see Fig. 1). Participants had to keep their finger pressed until the word appeared on the screen. According to the participants' approach/avoidance action, the whole visual environment (i.e., the background image and the target word) was zoomed in (i.e., approach, "move forward" button) or zoomed out (i.e., avoidance, "move backward" button) by 10% after each button press, giving the visual impression to walk forward or backward as a consequence of these actions. The stimuli, presented initially in font size 18 (Courier New typeface and white color given the dark background), could therefore vary from 30% larger (approach) to 30% smaller (avoidance). As soon as the target word appeared, participants had to categorize it as being positive or negative by pressing the end buttons (i.e., move forward/move backward buttons) as quickly and as accurately as possible. Specifically, in the compatible block participants had to "approach positive words and avoid negative words" and in the incompatible block to "avoid positive words and approach negative words". After four key presses in the same direction (i.e., for a complete forward or backward movement), the trial terminated. For each trial, we recorded response times from the appearance of the word to the first push on one of the two categorization buttons. This will be the dependent variable in all our experiments. As target words, we selected positive (8) and negative (8) words in the "Lexique" database (New, Pallier, Brysbaert, & Ferrand, 2004), so that positive words ($M = 3.18$, $SD = 0.24$) were significantly more positive than negative words ($M = -3.42$, $SD = 0.26$), $t(14) = 52.06$, $p < .001$ (on a -4 = *extremely negative* to $+4$ = *extremely positive* scale). The two groups of words did not differ significantly on their number of letters ($M_{pos} = 5.87$, $SD_{pos} = 1.64$; $M_{neg} = 6.87$, $SD_{neg} = 0.99$), $t(14) = 1.47$, $p = .16$, and frequency ($M_{pos} = 37.67$, $SD_{pos} = 24.71$; $M_{neg} = 34.89$, $SD_{neg} = 19.49$), $t(14) = 0.25$, $p = .81$.

4.1.4. The manikin task

In line with previous work (Krieglmeyer & Deutsch, 2010), we used a white background and the manikin (a little schematic figure), as well as the font color were black. When participants pressed the start button, a fixation cross was displayed (for a random duration of 550–950 ms, following Krieglmeyer & Deutsch, 2010), followed by the target word (displayed in the center of the screen in size 32, Arial typeface) and the manikin (displayed on the left or right side of the word) that appeared concurrently with the word. Participants were instructed to "approach positive words and avoid negative words" in the compatible block and to "avoid positive words and approach negative words" in the incompatible block. In this task, participants had to use the "left" and the "right" keys according to the position of the manikin (i.e., on the left or on the right). In this task, each key press moved the character closer or farther away from the target word. Again, we recorded the time between the target onset and the first key press.

4.2. Results and discussion

We tested whether using visual sensory information related to movements of the self enabled us to replicate the approach/avoidance compatibility effect. This analysis first revealed a compatibility main effect, $F(1, 26.97) = 12.73$, $p < .01$, with participants being faster in the compatible block ($M = 715$ ms, $SE = 14$ ms) than in the incompatible block ($M = 756$ ms, $SE = 17$ ms). More critically, and as can be seen in Fig. 2, the significant compatibility by task interaction revealed that the compatibility effect was larger in the VAAST than in the manikin task, $F(1, 46.24) = 6.73$, $p = .013$. As expected, our results revealed a larger compatibility effect in the VAAST, a task displaying the visual information related to movements of the self, than in the manikin task, a task not relying on sensory information, but known to produce large compatibility effects.

Simple effects analysis revealed a significant compatibility effect for the VAAST, $F(1, 37.84) = 23.36$ $p < .001$, indicating that participants were faster in the compatible ($M = 702$ ms, $SE = 13$ ms) than in the incompatible block ($M = 758$ ms, $SE = 15$ ms). It is also noteworthy, that, as can be seen in Table 2, the compatibility effect in the VAAST can be qualified as large (according to Cohen's criterion, 1992). In the manikin task, this analysis revealed a marginal and small (i.e., below 0.50) compatibility effect, $F(1, 26.34) = 3.70$, $p = .065$, indicating that participants tended to be faster in the compatible block ($M = 729$ ms, $SE = 18$ ms) than in the incompatible one ($M = 756$ ms, $SE = 20$ ms). Also importantly, Table 2 reveals that, for the VAAST, the compatibility effect was not only large, but also in the expected direction for most participants and for all stimuli.

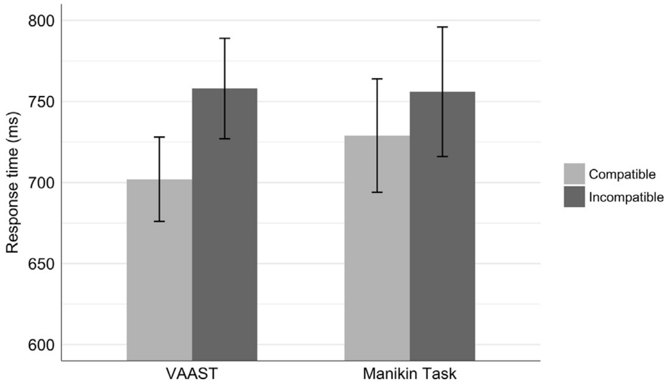

Fig. 2. Response time (ms) as function of task and compatibility. Error bars represent 95% confidence intervals.

5. Experiment 2

As we reasoned above, sensorimotor approach/avoidance tasks should simulate the visual aspects that come with movements of the whole-self (as the VAAST does) rather than arm movements (as a typical joystick task does). It follows that we should find larger compatibility effects when simulating the self moving toward or away from the stimulus (as the VAAST does) rather than a movement of the stimulus moving toward or away from the self (as the typical joystick task does when providing visual feedback; e.g., Krieglmeyer & Deutsch, 2010; Rinck & Becker, 2007). To test this prediction, we compared the VAAST with a slight variation of this task in which, instead of being asked to

Table 2
Effect size and direction of the effect according to the by-participant/by-stimuli analysis and according to the task across all experiments.

		Effect size (*dz*)		Effect in the expected direction (in percentage)	
Exp.	Task	By participants	By stimuli	By participants	By stimuli
Exp. 1	VAAST	0.89***	1.63***	81.25	100.00
	Manikin task	0.44**	0.44***	68.75	50.00
Exp. 2	Whole-body-action	0.78***	1.06***	78.43	80.00
	Action-on-the-stimulus	0.13^{ns}	0.14***	50.98	57.50
Exp. 3	Left/right	0.98***	1.78***	81.35	97.50
Exp. 4	Short movement	1.01***	2.21***	77.14	97.50
Exp. 5	Suboptimal	0.33**	0.41**	64.18	64.00
Exp. 6	VAAST	0.63***	1.51***	66.04	95.00
	No AA mentions	0.52***	1.03***	75.00	82.50
	No visual flow	0.21^{ns}	0.48**	63.46	72.50

AA = approach/avoidance.

$^{*}p < .05$.

** $p < .01$.

*** $p < .001$.

move the self toward or away from the stimulus (which comes with changes in visual angles for the stimulus *and* the surrounding environment), participants had to move the stimulus toward or away from them (which comes with changes in visual angles only for the stimulus). Therefore, in these two conditions, the surrounding environment was the same, but the visual cues simulated either an action of the whole-body (the VAAST labeled here the whole-body-action condition) or on the stimulus (the action-on-the-stimulus condition).

5.1. Method

5.1.1. Participants and design

Fifty-six students (*Mage* = 20.14, *SDage* = 2.37, 44 females) were recruited in exchange for course credit. We relied on a 2 (compatibility: compatible vs. incompatible) × 2 (condition: whole-body-action vs. action-on-the-stimulus) within-participants design. The stimuli were the same as in Experiment 1, except that we added 12 stimuli in each condition to increase statistical power for the mixed-model analysis (with the same dimensions controlled as in Experiment 1). The resulting 20 stimuli (for each condition) were presented twice in each block (amounting to 80-trial blocks).

5.1.2. Procedure

The procedure of Experiment 2 was similar to Experiment 1, the main difference being that participants performed the action-on-the-stimulus condition instead of the manikin task. Participants were seated in front of a chin rest set at a distance of 70 cm from the screen (60 Hz). They had to perform two tasks: the VAAST we used in Experiment 1 (labeled here the "whole-body-action" condition) and an "action-on-the-stimulus" condition. The action-on-the-stimulus condition was different from the whole-body-action condition on the following aspects. First, participants had to either "pull" the stimulus toward themselves (approach) or to "push" the stimulus away from themselves (avoidance), so the two buttons adjacent to the start button were labeled "pull" (instead of "move backward" in the whole-body-action condition) and "push" (instead of "move forward") respectively. Second, in the whole-body-action condition, the background image and the stimulus were moving according to the participants' action (i.e., zoomed in when participants moved forward and zoomed out when they moved backward) while in the action-on-the-stimulus condition, the background image stayed static, while the stimulus was moving (i.e., zoomed in when participants "pulled" the stimuli and zoomed out when they "pushed" the stimuli). These two differences concerning the button box and the visual feedback were consistent with what happens when one brings close or pushes away something. In both conditions, each key press impacted (i.e., increased or reduced) the stimulus size by 0.18 angular degrees.

5.2. Results and discussion

Following our rationale, our main prediction was that the compatibility effect should be larger in the whole-body-action condition than in the action-on-the-stimulus condition. Our results first revealed a compatibility main effect, $F(1, 62.41) = 15.72$, $p < .001$, with participants being faster in the compatible block ($M = 715$ ms, $SE = 13$ ms) than in the incompatible block ($M = 745$ ms, $SE = 15$ ms). More critically, the significant compatibility by task interaction revealed that the compatibility effect was larger in the whole-body-action condition than in the action-on-the-stimulus condition, $F(1, 58.10) = 12.03$, $p < .001$ (see Fig. 3). A simple effects analysis revealed a significant compatibility effect in the whole-body-action condition, $F(1, 64.58) = 24.26$ $p < .001$, with participants being faster in the compatible block ($M = 708$ ms, $SE = 13$ ms) than in the incompatible block ($M = 757$ ms, $SE = 17$ ms). Conversely, in the action-on-the-stimulus condition, this simple effect was not significant, $F(1, 53.22) = 0.78$, $p = .38$, although participants were descriptively faster in the compatible block ($M = 723$ ms, $SE = 15$ ms) than in the incompatible block ($M = 734$ ms, $SE = 16$ ms).

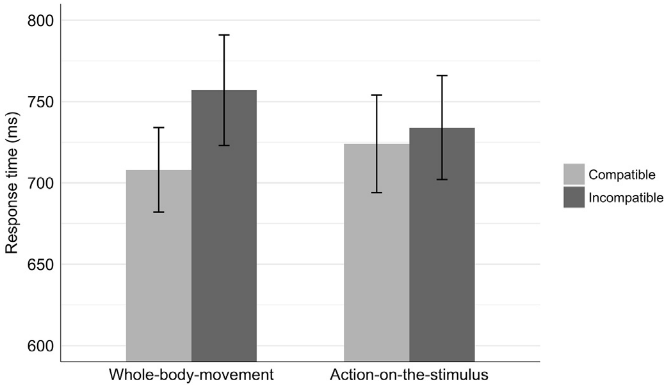

Fig. 3. Response Time (ms) as function of condition and compatibility. Error bars represent 95% confidence intervals.

The main goal of this experiment was to test whether simulating a movement of the whole-self instead of an action on the stimulus (like most versions of the joystick task do) produces a larger compatibility effect. Our results revealed that this is indeed the case. One potential issue with this experiment is that the two conditions differ not only in terms of the visually simulated actions, but also in terms of the slight difference in arm movements required to approach (extension and flexion, respectively for the whole-body-action and the action-on-the-stimulus conditions) or to avoid the stimulus (flexion and extension, respectively for the whole-body-action and the action-on-the-stimulus conditions). This should not be a concern, however, because following our rationale arm movements are not assumed to be critical in this task. The goal of Experiment 3 was to test this assumption.

6. Experiment 3

Unlike other sensorimotor approach/avoidance tasks (e.g., the joystick task, the modified keyboard), the compatibility effect in the VAAST is not supposed to be driven by arm movements. One could argue, however, that in our basic setting there were still short arm flexions/extensions associated with approach/avoidance (i.e., pressing the "forward" vs. "backward" response key; see Fig. 1). The goal of Experiment 3 was to test whether we could replicate our compatibility effect without such arm movements. To do so, we used a setting involving only left-right arm movements (i.e., not specifically related to approach/avoidance arm movements).

6.1. Method

6.1.1. Participants and design

Fifty-nine students (M_{age} = 20.35, SD_{age} = 1.84, 46 females) were recruited in exchange for course credit. In this experiment, we used a 2 (compatibility: compatible vs. incompatible) × 2 (key mapping: approach-on-the-right vs. approach-on-the-left) within-participants design. Given that the compatibility by key mapping interaction could have been moderated by participants' handedness (i.e., greater compatibility effect when approach was on the right for right-handed and the reverse pattern for left-handed participants; see Casasanto, 2009, for evidence of an association between positive valence and the side of the dominant hand), we recruited our sample to reach a decent number of left-handed participants (N = 22).

6.1.2. Procedure

The procedure was the same as in Experiment 1 with two exceptions. First, the response buttons were labeled as "left" and "right", so participants were instructed to approach vs. avoid stimuli by pushing the “left” or the “right” button. Second, the button box was positioned horizontally so that these two response keys were on the left or on the right of participants and therefore did not involve arm flexion/extension to be responded to. In two consecutive blocks of trials (one compatible block of 80 trials and one incompatible block of 80 trials), participants were instructed to approach (i.e., to “move forward”) by pushing the “right” button and to avoid (i.e., to “move backward”) by pushing the “left” button. These instructions were reversed for the other two consecutive blocks (“right” button for avoidance and “left” button for approach). At the end of the experiment, participants were asked about their handedness.

6.2. Results and discussion

The critical compatibility main effect was significant, $F(1, 74.05) = 44.58$, $p < .001$, with participants being faster in the compatible block ($M = 675$ ms, $SE = 11$ ms) than in the incompatible block ($M = 715$ ms, $SE = 12$ ms). This compatibility effect was moderated by key mapping, such that the compatibility effect was larger in the approach-on-the-right setting compared to the approach-on-the-left setting, $F(1, 64.81) = 4.28$, $p = .042$[2]. Even without a motor mapping, the compatibility effect produced in this experiment was large (in fact, descriptively larger than in the previous two experiments) and present for the vast majority of participants and stimuli (see Table 2). These results suggest that the compatibility effect produced in the VAAST does not depend on the forward-backward motor arm movements.

7. Experiment 4

In Experiment 1, participants had to press the keys four times to complete a forward/backward movement. This simulates situations where someone walks several steps toward or away from a stimulus. One can doubt, however, that this is the most prototypical approach/avoidance experience, because one rarely walks several steps backward. Therefore, in Experiment 4 we tested whether we could replicate the compatibility effect when simulating only a short movement toward or away from the stimulus (using one key press and the associated short visual flow). In addition, to provide visual information as similar as possible to a real-life experience, we removed the headshot.[3] Finally, we changed the nature of the environment, because our compatibility effect should not be restrained to a single background type.

7.1. Method

7.1.1. Participants and design

Thirty-five participants[4] ($M_{age} = 22.42$, $SD_{age} = 5.51$, 28 females) took part in exchange for course credit. In this experiment, we used a 2 (compatibility: compatible vs. incompatible) within-participants design.

7.1.2. Procedure

The procedure was the same as in Experiment 1 except for a few modifications. First, in this experiment, participants had to press only once the “forward” vs. “backward” response key to complete a trial, and this triggered a short visual flow. Second, we removed the headshot and for the visual environment we generated a 3D regular street (and not a corridor) in Blender© (see Fig. 4).

Fig. 4. Background used in Experiments 4 and 6.

7.2. Results and discussion

The critical compatibility main effect was significant, $F(1, 39.09) = 32.66$, $p < .001$, with participants being faster in the compatible block ($M = 701$ ms, $SE = 21$ ms) than in the incompatible block ($M = 772$ ms, $SE = 20$ ms). In addition, Table 2 shows this effect was large and present for the vast majority of participants and stimuli. In other words, we replicated a strong compatibility effect even with a short approach/avoidance movement, without the headshot, and with a different background.

8. Experiment 5

Although several studies were able to do so (e.g., Chen & Bargh, 1999; Slepian, Young, Rule, Weisbuch, & Ambady, 2012; Wentura et al., 2000), other work struggled to find compatibility effects without an explicit evaluative goal in sensorimotor approach/avoidance tasks. This led some authors to conclude for an “absence of evidence for an effect with implicit evaluation” (Phaf, Mohr, Rotteveel, & Wicherts, 2014). The goal of Experiment 5 was therefore to test whether a task simulating the sensorimotor information we put forward in this contribution could produce a compatibility effect even when participants were not asked to process the valence of words. In addition, and to strengthen this demonstration, the presentation of these words was highly degraded (or even arguably subliminally presented) and to ensure it was the case, participants performed a forced-choice recognition task (after the VAAST) enabling us to argue that participants did not explicitly process these stimuli.

8.1. Method

8.1.1. Participants and design

Sixty-seven participants ($M_{age} = 20.25$, $SD_{age} = 1.58$, 60 females) took part in exchange for 10 euros. In this experiment, we used a 2 (trial compatibility: compatible vs. incompatible) within-participants design. To further increase statistical power for the mixed-model analysis, we used the same set of 40 words used in Experiments 2, 3, and 4, but added 5 words in each valence condition (with the same dimension controlled as previously). Each word was presented twice before an approach movement and twice before an avoidance movement.

8.1.2. Procedure

The visual environment, response labels, and number of key presses for approach/avoidance were those we used in Experiment 1. There were, however, two important differences related to the degraded presentation of the positive and negative words. First, these words were presented for a very short duration (i.e., 30 ms) with a pre-mask (i.e.,

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[2] Without the key mapping variable, the compatibility effect is still large and significant, $F(1, 73.21) = 44.94$, $p < .001$, $dz = 0.98$ and $dz = 1.78$ respectively for the by-participants and the by-stimuli analyses.

[3] In a pilot experiment, we used the same visual environment as in Experiment 4 (i.e., the visual environment presented in Fig. 4 with no headshot), but relying on four key presses for approach/avoidance actions as in Experiments 1–3, 5, and 6. We found a significant compatibility effect, $F(1, 53.39) = 58.99$, $p < .001$, of a similar magnitude ($dz = 1.16$ and $dz = 1.76$ respectively for the by-participant and by-stimuli analyses).

[4] A 36th participant started the experiment, but decided to quit halfway through the task.

the sequence of letters “WXWXWXWXW” for 50 ms) and a post-mask (i.e., the sequence of letters “@W@W@W@W” for 50 ms). Second, the target stimulus was not a word, but a series of letters (e.g., “nlkjdsOaq”) and participants had to determine whether this letter string contained a capital letter. Half of the participants had to approach letter strings that contained an uppercase letter and avoid those that did not (e.g., approach “nlkjdsOaq” and avoid “nlkjdsoaq”), while the other half had the opposite instructions (e.g., approach “nlkjdsoaq” and avoid “nlkjdsOaq”). After the VAAST, participants performed a forced-choice recognition task in which they had to guess, at the end of each trial, which word was presented between two possible options (two options presented before the beginning of the trial and using a foil that was always of the same valence). Across 50 trials, each positive and negative word of the experimental phase was presented once as a target word (i.e., the one presented briefly) with the same time course and with the same background image as in the main experiment. The response time was unconstrained and the number of correct responses was recorded[5].

8.2. Results and discussion

8.2.1. Forced-choice recognition task

We analyzed the rates of correct responses and false alarms. Using a signal detection theory approach, we calculated a d' representing to what extent participants differentiated the signal from the noise. The averaged d' we found was not significantly different from zero, $d' = -0.025$, 95% CI $[-0.11; 0.06]$ and the confidence interval was descriptively tightened around zero. This result indicates that participants did not seem to differentiate significantly the signal from the noise in this forced-choice recognition task. In other words, it seems that participants were not able to identify these words. Nonetheless, to avoid relying on acceptance of the null hypothesis, we used a procedure inspired by Greenwald, Draine, and Abrams (1996) and analyzed the results of the VAAST with a mixed-model estimating our compatibility effect for a d' equal to zero.

8.2.2. VAAST

We estimated a model crossing compatibility and d' values as fixed effects (doing so enables us to test the compatibility effect for d' equals 0; see Judd, Yzerbyt, & Muller, 2014). The resulting compatibility effect was descriptively smaller than in the previous experiments (see Table 2), but still significant, $F(1, 48.94) = 4.99$, $p = .030$. In other words, for $d' = 0$, participants were faster for compatible trials ($M = 751$ ms, $SE = 13$ ms) than for incompatible trials ($M = 760$ ms, $SE = 13$ ms). Therefore, it seems that when relying on what we reasoned should be the most relevant sensorimotor information, a compatibility effect can be found even when participants: 1) are not asked to process the valence of the words and 2) do not seem to correctly perceive these words. To the best of our knowledge, this is the first experiment to produce such a compatibility effect at zero perceptibility of the valenced stimuli[6] (i.e., using the Greenwald et al.'s, 1996 procedure that avoids testing and accepting the null hypothesis of zero perceptibility).

9. Experiment 6

The last experiment tackles two questions: First, could we attribute all our previous findings to the correspondence between the valence of the labels we used for the response keys (approach and avoidance being respectively positive and negative; Eder & Rothermund, 2008) and the valence of the stimuli? Our theoretical framework leads us to expect that the compatibility effect should stand in a condition devoid of these approach/avoidance labels. The second question we wanted to tackle is whether the compatibility effect depends, as we hypothesized, on the visual flow. Therefore, we compared a regular VAAST condition with a condition without visual flow and we expected the compatibility effect to be reduced in this latter condition. We addressed these two questions in a three-condition design comparing a regular VAAST with a “no approach/avoidance mentions” condition and a “no visual flow” condition.

9.1. Method

9.1.1. Participants and design

One hundred and fifty-seven participants ($M_{age} = 21.07$, $SD_{age} = 3.41$, 106 females) took part in exchange for 10 euros. The design was a 2 (compatibility: compatible vs. incompatible) × 3 (condition: VAAST vs. no approach/avoidance mentions vs. no visual flow) with the last variable being between-participants. Participants were randomly assigned to one of these three conditions.

9.1.2. Procedure

In the VAAST condition, the procedure was the same as in Experiment 4 except two differences. First, the number of key presses to approach/avoid stimuli was the same as in Experiments 1, 2, 3, and 5 (i.e., four key presses). Second, instead of instructing participants to “move forward (move backward) to approach (avoid) positive (negative) words by pushing the ‘forward’ (‘backward’) button” (or the reverse in the incompatible block), we instructed them to “push the ‘forward’ (‘backward’) button for positive (negative) words” (or the reverse in the incompatible block). This allowed us to keep instructions as similar as possible across conditions. In the “no approach/avoidance mentions” condition, the only difference with the VAAST condition was that we never mentioned approach/avoidance neither in the instructions nor in the labels. Participants were instructed to “push button ‘A’ for positive words” and to “push button ‘B’ for negative words” (or the reverse in the incompatible block). Buttons A and B were always respectively associated with approach and avoidance visual flows. Finally, in the “no visual flow” condition, instructions and labels were the same as in the VAAST condition, but no visual flows were generated.

9.2. Results and discussion

First, we found a significant compatibility main effect, $F(1, 153.81) = 25.96$, $p < .001$, with participants being faster in the compatible block ($M = 718$ ms, $SE = 8$ ms) than in the incompatible block ($M = 752$ ms, $SE = 9$ ms). We also found a significant compatibility by condition interaction, $F(2, 153.98) = 3.34$, $p = .035$. More important, to be able to compare the VAAST with each condition, we relied on a set of two dummy codings comparing the VAAST and each of the other two conditions (because these two tests were not orthogonal, we applied a Bonferroni correction, leaving us with a significant threshold of $\alpha = .025$). This analysis revealed, on the one hand, that the VAAST and the “no approach/avoidance mentions” condition did no differ significantly, $F(1, 153.68) = 1.33$, $p = .25$. On the other hand, it revealed that the VAAST differed significantly from the “no visual flow” condition, $F(1, 153.60) = 6.67$, $p = .01$ (see Fig. 5). Therefore, this means that removing the visual flow led to a reduction in the compatibility effect as compared with the VAAST condition. In fact, further simple effect analyses revealed that the compatibility effect was significant in the VAAST, $F(1, 164.78) = 24.60$, $p < .001$, and in the no approach/avoidance mentions conditions, $F(1, 164.42) = 11.16$, $p < .01$, but not in the no visual flow condition, $F(1, 164.25) = 1.90$, $p = .17$. In sum, this experiment shows that we can still produce a compatibility

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[5] At the end of this experiment and for exploratory purposes, we also asked participants to rate the valence of all the stimuli. Because we collected this measure only in this experiment, it will not be discussed further.

[6] Arnaudova, Krypotos, Effting, Kindt, and Beckers (2017) recently published an experiment using the manikin task in which they were able to produce a compatibility effect, while having a similar test of perceptibility. In contrast with the current analysis, however, they did not test this effect for a zero level of perceptibility (they relied on the null hypothesis of no perceptibility).

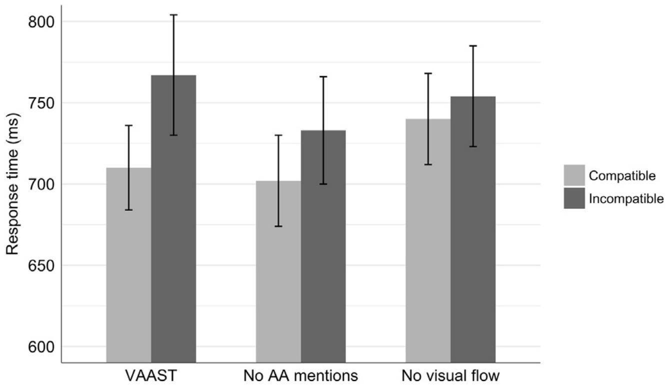

Fig. 5. Response Time (ms) as function of task and compatibility. Error bars represent 95% confidence intervals.

effect even without referring to approach/avoidance terms. It also shows that, everything else being constant, removing the visual flow mitigates the compatibility effect. It is worth mentioning that, although the compatibility effect in the VAAST condition is still medium in size and in the expected direction for a large majority of participants and stimuli, it is descriptively smaller than in the other comparable experiments (see Table 2).

10. General discussion

Seminal experiments in the approach/avoidance literature relied on arm movements (Cacioppo, Priester, & Berntson, 1993; Chen & Bargh, 1999). Recent work, however, raised doubts regarding how critical this kind of sensorimotor information might be in producing approach/avoidance compatibility effects (e.g., Krieglmeyer & Deutsch, 2010; Rotteveel et al., 2015). Here, we argue that a sensorimotor task (i.e., in which the sensorimotor aspects are thought to be crucial in producing the effect) can produce large and replicable compatibility effects. This kind of task can do so to the extent that one relies on sensorimotor aspects that are related to the visual component (instead of the motor component) of movements that involve the whole-self (instead of movements on the stimulus, as it was the case with arm movements). To test this idea, we developed a new task (the VAAST) that simulates this visual information and examined whether such a task produces strong and replicable compatibility effects with valenced words.

The goal of Experiment 1 was twofold: to provide a preliminary test of this task and to test whether this sensorimotor task could perform as well as (or even better than) a non-sensorimotor task (i.e., the manikin task) known to produce reliable compatibility effects, and in fact stronger compatibility effect than the often-used joystick task (relying on arm movements). This experiment showed that the VAAST produced a large compatibility effect and that this effect was larger than the one produced by the manikin task. In Experiment 2, we showed that a task (i.e., the VAAST) simulating a whole-body action produced a larger compatibility effect than a task simulating an action on the stimulus (as the joystick task does). In the next three experiments, we showed we could replicate the VAAST compatibility effect when taking out aspects that are not critical in producing the effect according to our framework. First, because we believe arm movements (i.e., flexion and extension) should not be instrumental, in Experiment 3 we replicated the effect with a version involving only left and right arm movements. Second, because the original VAAST simulated several steps forward or backward and because the most basic approach/avoidance movements might be relatively short, in Experiment 4 we replicated the effect with a version of the VAAST simulating only a shorter movement forward or backward. Third, in Experiment 5 we replicated the effect without an explicit evaluative goal and when the presentation of valenced words was highly degraded (some would say subliminally presented). The goal of our last experiment was twofold: first, to test whether a compatibility effect could be found with the VAAST even when neither the instructions, nor the labels mentioned approach/avoidance and, second, to test, in comparison with a standard version of the VAAST, whether removing the visual flow would significantly reduce the compatibility effect. This experiment revealed that we could replicate the compatibility effect without mentioning approach/avoidance and that removing the visual flow significantly reduced the compatibility effect (to the point of not being significant).

Three aspects are worth mentioning in relation to the strength of the compatibility effect found in these experiments. First, we found a single other study that tested the approach/avoidance compatibility effect while using mixed-models (Carr, Rotteveel, & Winkielman, 2016). From a replication perspective, this is important because using such models enables us to generalize our results not only to other participants, but to other stimuli as well (Judd et al., 2012). Second, in most of our experiments, the effect sizes produced by the VAAST were large, being rarely medium, and small only once when relying on an incidental task (participants were not asked to process the stimuli) with a highly degraded presentation of the stimuli. Third, by-participants and by-stimuli

Table 3
Mean (standard error) response time as function of movement and valence, as well as difference between positive and negative stimuli.

Experiment	Task	Movement	Positive valence	Negative valence	Difference (Neg.–Pos.)	
Exp. 1	VAAST	Approach	700 (27)	734 (29)	34	$p < .05$
		Avoidance	734 (29)	701 (23)	−33	$p < .001$
	Manikin task	Approach	712 (30)	726 (31)	14	$p = .17$
		Avoidance	767 (31)	739 (29)	−28	$p = .06$
Exp. 2	Whole-body-action	Approach	693 (25)	742 (29)	49	$p < .001$
		Avoidance	754 (29)	719 (25)	−35	$p < .01$
	Action-on-the-stimulus	Approach	720 (26)	723 (27)	3	$p = .66$
		Avoidance	728 (28)	718 (25)	−10	$p = .58$
Exp. 3	Left/right	Approach	665 (22)	704 (24)	39	$p < .001$
		Avoidance	718 (24)	680 (21)	−38	$p < .01$
Exp. 4	Short movement	Approach	688 (31)	759 (33)	71	$p < .001$
		Avoidance	777 (33)	706 (29)	−71	$p < .001$
Exp. 5	Suboptimal	Approach	734 (25)	747 (26)	13	$p = .010$
		Avoidance	762 (26)	754 (26)	−8	$p = .19$
Exp. 6	VAAST	Approach	701 (25)	756 (30)	55	$p < .001$
		Avoidance	755 (29)	715 (24)	−40	$p < .01$
	No AA mentions	Approach	698 (26)	726 (27)	28	$p < .05$
		Avoidance	725 (28)	699 (24)	−27	$p = .075$
	No visual flow	Approach	731(26)	747 (26)	16	$p = .096$
		Avoidance	750 (27)	744 (25)	6	$p = .84$

descriptive analyses for the VAAST showed that our results were in the expected direction for very high proportions of participants and stimuli (often around 80% or above; see Table 2). Finally, beyond the results in terms of compatibility effects, the pattern of means corresponding to the movement (approach vs. avoidance) by valence (positive vs. negative) interaction also speak to the strength of our findings (see Table 3). Indeed, these means reveal that every single condition simulating the two features we put forward led (descriptively) to the expected pattern for the two critical simple effects, namely participants being faster for positive than for negative words for approach movements, and vice versa for avoidance movements. In addition, 12 of these 14 simple effects were significant, while 1 was marginal, and 1 was non-significant.

10.1. Contributions to research on approach/avoidance

The first contribution of the current experiments is to introduce a new approach/avoidance task that systematically produces an often large compatibility effect when using clearly valenced stimuli. Importantly, this task does not raise interpretative issues that the most commonly used sensorimotor approach/avoidance task can raise (e.g., is arm flexion an approach or an avoidance movement?). In addition, it does all this without requiring specific hardware material (in these experiments we used button boxes, but in other experiments we replicated these effects also when using regular keyboards and even online versions of the task) or high-level programming.

The second contribution speaks to the underlying processes driving the approach/avoidance compatibility effects. Indeed, the results of our experiments are not easily explained by three of the most influential hypotheses (Kozlik et al., 2015; Krieglmeyer, De Houwer, & Deutsch, 2013). The first one, the "distance change hypothesis", argues that valenced stimuli automatically activate approach/avoidance motivational orientations, having the function of decreasing/increasing the self-stimulus distance (no matter the movement implied for this action; e.g., Krieglmeyer & Deutsch, 2010; Krieglmeyer et al., 2011). Given that, for instance, in Experiments 1 and 2, each approach/avoidance action resulted in a similar decrease vs. increase of the stimulus distance, it is hard to see how this hypothesis could explain our results.

The second hypothesis, the "evaluative coding hypothesis", argues that approach/avoidance compatibility effects are due to the compatibility between the valence of the stimuli and the affective connotation of approach (seen as positive by participants) and avoidance (seen as negative by participants; Eder & Rothermund, 2008). Three of our results might be difficult to reconcile with this hypothesis. First, it is unclear how it could explain the results of Experiment 2 where we found a larger compatibility effect in the whole-body-action condition as compared with the action-on-the-stimulus condition. Because one might argue that the difference in valence between forward and backward (the labels used in the former condition) is larger than the difference between pull and push (the labels used in the latter condition), we recruited 487 additional participants who rated the valence of 14 actions among which four were related to these four actions (e.g., "pushing something"). These data revealed that the difference between forward and backward was not significantly larger than the difference between pull and push, $t(486) = 0.28$, $p = .78$, $\eta_p^2 = .0002$. Second, it is also unclear how this hypothesis could account for the results of Experiment 5 because the stimuli were not explicitly categorized on their affective dimension. Finally, in Experiment 6 we found a significant compatibility effect even when neither the instructions nor the labels mentioned approach/avoidance. Now, regarding these first two hypotheses we would like to mention that it is not because we present data we think underline the importance of sensorimotor aspects in producing approach/avoidance compatibility effect that we challenge the existence of "non-sensorimotor" approach/avoidance compatibility effects (like the one found for instance in Eder & Rothermund, 2008, Krieglmeyer, Deutsch, De Houwer, & De Raedt, 2010, or Markman & Brendl, 2005). We claim, however, that the visual information associated with movements of the self have their merits as well in driving these effects.

The third and last hypothesis is the "specific muscle activation" hypothesis. This account assumes hard-wired associations between stimulus evaluations and specific motor responses (Cacioppo et al., 1993; Chen & Bargh, 1999). This hypothesis has already been challenged, for instance by studies showing a reversal in arm flexion/extension meaning (Seibt et al., 2008). One could argue, however, that this hypothesis should be reassessed now that researchers start to study approach/avoidance with whole-body movements (Kozlik et al., 2015). For instance, as we mentioned in introduction, previous work has used whole-body movements approach/avoidance as a manipulation (Fayant et al., 2011; Koch et al., 2009), but also as an approach/avoidance measure (Ly et al., 2014; Stins et al., 2011). Because this last kind of studies use real whole-body movements (i.e., participants literally move in the room), they specifically illustrate that approach/avoidance compatibility effects are possible when providing both motor and visual information coming with movements of the self. They do not allow, however, to easily compare the compatibility effect when providing the visual aspects of whole-body movements versus action on the stimulus, as we did in Experiment 2. Indeed, studies relying on actual whole-body movements make it more difficult to isolate visual and motor modalities. In the current work, we were able to do so in Experiment 3 and to demonstrate that the visual modality was sufficient to produce approach/avoidance compatibility effects, which challenges a strong version of the specific muscle activation hypothesis that would focus only on muscle (and therefore motor) activation. Of course, our experiments do not speak to the possibility of having a compatibility effect when providing (whole-body) motor information, but no visual information. For instance, such study would require relying on actual whole-body movements, without visual stimulations (maybe by using auditory stimuli). Finally, future work could pit against each other the role of motor and visual modalities by relying on virtual reality technologies. Such work could enable to decouple motor actions (e.g., chest movements) and visual feedback and therefore to directly contrast one with the other.

To reassess the importance of sensorimotor aspects in the study of approach/avoidance, we reconsidered how people typically behave and what they perceive while doing so. In other words, we relied on the fundamental idea that cognition (here the cognitive processes involved in approach/avoidance) is grounded (e.g., Barsalou, 1999; van Dantzig et al., 2009; Versace et al., 2014). Therefore, we believe that a grounded cognition framework provides the best explanation for our results. In this framework, the cognitive system is assumed to keep track of the brain stimulation across the different modalities involved when perceiving, acting, and reacting to a given stimulus (Barsalou, 2008; Niedenthal, 2007). Applying this principle to approach/avoidance, it means that, if most of the time people approach positive stimuli, their representation of these stimuli contain sensorimotor stimulations associated with approach/avoidance actions: Positive (vs. negative) stimuli should be predominantly associated with a looming (vs. receding) visual flow typical of the self approaching (vs. avoiding) the stimulus. Hence, a grounded cognition approach predicts a crucial role of such sensorimotor information in approach/avoidance tasks: The compatibility between the (automatically reactivated) visual information associated with stimuli and the (simulated) visual information in the task should facilitate the performance of the corresponding action. In addition, because the visual system is arguably the most prevalent modality in human beings (Nørretranders, 1998; Posner et al., 1976), it would account for the role of the visual information in our findings.

10.2. Limitations and future directions

First, because in this work our main goal was to test the importance of sensory (visual) information on generic approach/avoidance tendencies, we chose to focus our attention on clearly valenced words. It is worth mentioning, however, that the VAAST has already been used successfully to produce compatibility effects with other kinds of materials like for instance ingroup/outgroup first names (Rougier, Muller, Courset, Smeding, & Ric, in preparation). In light of the current Experiment 2, it can be easily conceived that it might be more prototypical to walk toward or away from other people, instead of pulling or pushing them away from us, which makes this task even more relevant in this context. Accordingly, although previous work could show that people are faster to pull a joystick for trustworthy faces and to push a joystick for untrustworthy faces (rather than the opposite pattern; Slepian et al., 2012), we would predict that such a compatibility effect should be larger in a whole-body movement condition.

The goal of the current experiments was to reevaluate how critical sensorimotor aspects might be in producing compatibility effects. Doing so already suggests that the VAAST might be a promising approach/avoidance measure, but the current work leaves it to future work to assess the psychometric properties of this task. For instance, one intriguing question could be whether the VAAST might be a reliable indirect measure regarding approach/avoidance tendencies toward ingroup and outgroup members and whether it would capture personal evaluation vs. general cultural knowledge like indirect (or implicit) measures sometimes do.

11. Conclusion

This work was originally motivated by the need to find a paradigm producing a strong and reliable approach/avoidance compatibility effect. Drawing on the grounded cognition framework, we went for paradigms relying on motor compatibility, namely pressing vs. withdrawing the finger, large arm movements with a modified keyboard, and more modest arm movements with the joystick. All these experiments failed to reveal clear compatibility effects. The experiments reported here, however, suggest that going back to the basic assumptions of the grounded cognition framework might sometimes ironically imply to downplay the importance of motor aspects, in favor of visual ones. Doing so enabled us to derive original and heuristic hypotheses in conjunction with a task that consistently produced strong and robust compatibility effects.

Open practices

The data and the R scripts for all the reported experiments can be found at http://osf.io/hd6fw. We also provide examples of E-prime© scripts and material that can be used to implement the VAAST.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jesp.2017.12.004.

References

Alexopoulos, T., & Ric, F. (2007). The evaluation-behavior link: Direct and beyond valence. *Journal of Experimental Social Psychology, 43*, 1010–1016. http://dx.doi.org/10.1016/j.jesp.2006.10.017.

Arnaudova, I., Krypotos, A.-M., Effting, M., Kindt, M., & Beckers, T. (2017). Moving threat: Attention and distance change interact in threat responding. *Emotion, 17*, 251–258. http://dx.doi.org/10.1037/emo0000219.

Barsalou, L. W. (1999). Perceptions of perceptual symbols. *Behavioral and Brain Sciences, 22*, 637–660. http://dx.doi.org/10.1017/S0140525X99532147.

Barsalou, L. W. (2008). Grounded cognition. *Annual Review of Psychology, 59*, 617–645. http://dx.doi.org/10.1146/annurev.psych.59.103006.093639.

Cacioppo, J. T., Priester, J. R., & Berntson, G. G. (1993). Rudimentary determinants of attitudes: II. Arm flexion and extension have differential effects on attitudes. *Journal of Personality and Social Psychology, 65*, 5–17. http://dx.doi.org/10.1037/0022-3514.65.1.5.

Carr, E. W., Rotteveel, M., & Winkielman, P. (2016). Easy moves: Perceptual fluency facilitates approach-related action. *Emotion, 16*, 540–552. http://dx.doi.org/10.1037/emo0000146.

Casasanto, D. (2009). Embodiment of abstract concepts: Good and bad in right- and left-handers. *Journal of Experimental Psychology: General, 138*, 351–367. http://dx.doi.org/10.1037/a0015854.

Chen, M., & Bargh, J. A. (1999). Consequences of automatic evaluation: Immediate behavioral predispositions to approach or avoid the stimulus. *Personality and Social Psychology Bulletin, 25*, 215–224. http://dx.doi.org/10.1177/0146167299025002007.

Cohen, J. (1992). A power primer. *Psychological Bulletin, 112*, 155–159. http://dx.doi.org/10.1037/0033-2909.112.1.155.

De Houwer, J., Crombez, G., Baeyens, F., & Hermans, D. (2001). On the generality of the affective Simon effect. *Cognition & Emotion, 15*, 189–206. http://dx.doi.org/10.1080/02699930125883.

Eder, A. B., & Rothermund, K. (2008). When do motor behaviors (mis)match affective stimuli? An evaluative coding view of approach and avoidance reactions. *Journal of Experimental Psychology: General, 137*, 262–281. http://dx.doi.org/10.1037/0096-3445.137.2.262.

Fayant, M.-P., Muller, D., Nurra, C., Alexopoulos, T., & Palluel-Germain, R. (2011). Moving forward is not only a metaphor: Approach and avoidance lead to self-evaluative assimilation and contrast. *Journal of Experimental Social Psychology, 47*, 241–245. http://dx.doi.org/10.1016/j.jesp.2010.07.013.

Greenwald, A. G., Draine, S. C., & Abrams, R. L. (1996). Three cognitive markers of unconscious semantic activation. *Science (New York, N.Y.), 273*, 1699–1702. http://dx.doi.org/10.1126/science.273.5282.1699.

Judd, C. M., Westfall, J., & Kenny, D. A. (2012). Treating stimuli as a random factor in social psychology: A new and comprehensive solution to a pervasive but largely ignored problem. *Journal of Personality and Social Psychology, 103*, 54–69. http://dx.doi.org/10.1037/a0028347.

Judd, C. M., Yzerbyt, V. Y., & Muller, D. (2014). Mediation and moderation. In H. T. Reis, & C. M. Judd (Eds.). *Handbook of research methods in social and personality psychology* (pp. 653–676). (2nd ed.). New York: Cambridge University Press.

Koch, S., Holland, R. W., Hengstler, M., & van Knippenberg, A. (2009). Body locomotion as regulatory process: Stepping backward enhances cognitive control. *Psychological Science, 20*, 549–550. http://dx.doi.org/10.1111/j.1467-9280.2009.02342.x.

Kozlik, J., Neumann, R., & Lozo, L. (2015). Contrasting motivational orientation and evaluative coding accounts: On the need to differentiate the effectors of approach/avoidance responses. *Frontiers in Psychology, 6*. http://dx.doi.org/10.3389/fpsyg.2015.00563.

Krieglmeyer, R., De Houwer, J., & Deutsch, R. (2011). How farsighted are behavioral tendencies of approach and avoidance? The effect of stimulus valence on immediate vs. ultimate distance change. *Journal of Experimental Social Psychology, 47*, 622–627. http://dx.doi.org/10.1016/j.jesp.2010.12.021.

Krieglmeyer, R., De Houwer, J., & Deutsch, R. (2013). On the nature of automatically triggered approach-avoidance behavior. *Emotion Review, 5*, 280–284. http://dx.doi.org/10.1177/1754073913477501.

Krieglmeyer, R., & Deutsch, R. (2010). Comparing measures of approach–avoidance behaviour: The manikin task vs. two versions of the joystick task. *Cognition & Emotion, 24*, 810–828. http://dx.doi.org/10.1080/02699930903047298.

Krieglmeyer, R., Deutsch, R., De Houwer, J., & De Raedt, R. (2010). Being moved: Valence activates approach-avoidance behavior independently of evaluation and approach-avoidance intentions. *Psychological Science, 21*, 607–613. http://dx.doi.org/10.1177/0956797610365131.

Lavender, T., & Hommel, B. (2007). Affect and action: Towards an event-coding account. *Cognition & Emotion, 21*, 1270–1296. http://dx.doi.org/10.1080/02699930701438152.

Ly, V., Huys, Q. J. M., Stins, J. F., Roelofs, K., & Cools, R. (2014). Individual differences in bodily freezing predict emotional biases in decision making. *Frontiers in Behavioral Neuroscience, 8*. http://dx.doi.org/10.3389/fnbeh.2014.00237.

Markman, A. B., & Brendl, C. M. (2005). Constraining theories of embodied cognition. *Psychological Science, 16*, 6–10. http://dx.doi.org/10.1111/j.0956-7976.2005.00772.x.

New, B., Pallier, C., Brysbaert, M., & Ferrand, L. (2004). Lexique 2: A new French lexical database. *Behavior Research Methods, Instruments, & Computers, 36*, 516–524. http://dx.doi.org/10.3758/BF03195598.

Niedenthal, P. M. (2007). Embodying emotion. *Science, 316*, 1002–1005. http://dx.doi.org/10.1126/science.1136930.

Nørretranders, T. (1998). *The user illusion*. J. Sydenham, Trans.New York: Viking.

Paladino, M.-P., & Castelli, L. (2008). On the immediate consequences of intergroup categorization: Activation of approach and avoidance motor behavior toward ingroup and outgroup members. *Personality and Social Psychology Bulletin, 34*, 755–768. http://dx.doi.org/10.1177/0146167208315155.

Phaf, R. H., Mohr, S. E., Rotteveel, M., & Wicherts, J. M. (2014). Approach, avoidance, and affect: A meta-analysis of approach-avoidance tendencies in manual reaction time tasks. *Frontiers in Psychology, 5*. http://dx.doi.org/10.3389/fpsyg.2014.00378.

Posner, M. I., Nissen, M. J., & Klein, R. M. (1976). Visual dominance: An information-processing account of its origins and significance. *Psychological Review, 83*, 157–171. http://dx.doi.org/10.1037/0033-295X.83.2.157.

Proffitt, D. R., & Linkenauger, S. A. (2013). Perception viewed as a phenotypic expression. In W. Prinz, M. Beisert, & A. Herwig (Eds.). *Action science: Foundations of an emerging discipline* (pp. 171–198). Cambridge, MA: MIT Press.

Ratcliff, R. (1993). Methods for dealing with reaction time outliers. *Psychological Bulletin, 114*, 510–532. http://dx.doi.org/10.1037/0033-2909.114.3.510.

Rinck, M., & Becker, E. S. (2007). Approach and avoidance in fear of spiders. *Journal of Behavior Therapy and Experimental Psychiatry, 38*, 105–120. http://dx.doi.org/10.1016/j.jbtep.2006.10.001.

Rotteveel, M., Gierholz, A., Koch, G., van Aalst, C., Pinto, Y., Matzke, D., ... Wagenmakers, E.-J. (2015). On the automatic link between affect and tendencies to approach and avoid: Chen and Bargh (1999) revisited. *Frontiers in Psychology, 6*. http://dx.doi.org/10.3389/fpsyg.2015.00335.

Rotteveel, M., & Phaf, R. H. (2004). Automatic affective evaluation does not automatically predispose for arm flexion and extension. *Emotion, 4*, 156–172. http://dx.doi.org/10.1037/1528-3542.4.2.156.

Seibt, B., Neumann, R., Nussinson, R., & Strack, F. (2008). Movement direction or change in distance? Self- and object-related approach-avoidance motions. *Journal of Experimental Social Psychology, 44*, 713–720. http://dx.doi.org/10.1016/j.jesp.2007.04.013.

Slepian, M. L., Young, S. G., Rule, N. O., Weisbuch, M., & Ambady, N. (2012). Embodied impression formation: Social judgments and motor cues to approach and avoidance. *Social Cognition, 30*, 232–240. http://dx.doi.org/10.1521/soco.2012.30.2.232.

Solarz, A. K. (1960). Latency of instrumental responses as a function of compatibility with the meaning of eliciting verbal signs. *Journal of Experimental Psychology, 59*, 239–245.

Stins, J. F., Roelofs, K., Villan, J., Kooijman, K., Hagenaars, M. A., & Beek, P. J. (2011). Walk to me when I smile, step back when I'm angry: Emotional faces modulate whole-body approach–avoidance behaviors. *Experimental Brain Research, 212*, 603–611. http://dx.doi.org/10.1007/s00221-011-2767-z.

Vaes, J., Paladino, M. P., Castelli, L., Leyens, J.-P., & Giovanazzi, A. (2003). On the behavioral consequences of infrahumanization: The implicit role of uniquely human emotions in intergroup relations. *Journal of Personality and Social Psychology, 85*, 1016–1034. http://dx.doi.org/10.1037/0022-3514.85.6.1016.

van Dantzig, S., Pecher, D., & Zwaan, R. A. (2008). Approach and avoidance as action effects. *The Quarterly Journal of Experimental Psychology, 61*, 1298–1306. http://dx.doi.org/10.1080/17470210802027987.

van Dantzig, S., Zeelenberg, R., & Pecher, D. (2009). Unconstraining theories of embodied cognition. *Journal of Experimental Social Psychology, 45*, 345–351. http://dx.doi.org/10.1016/j.jesp.2008.11.001.

Versace, R., Vallet, G. T., Riou, B., Lesourd, M., Labeye, É., & Brunel, L. (2014). Act-in: An integrated view of memory mechanisms. *Journal of Cognitive Psychology, 26*, 280–306. http://dx.doi.org/10.1080/20445911.2014.892113.

Wentura, D., Rothermund, K., & Bak, P. (2000). Automatic vigilance: The attention-grabbing power of approach-and avoidance-related social information. *Journal of Personality and Social Psychology, 78*, 1024. http://dx.doi.org/10.1037/0022-3514.78.6.1024.

Westfall, J., Kenny, D. A., & Judd, C. M. (2014). Statistical power and optimal design in experiments in which samples of participants respond to samples of stimuli. *Journal of Experimental Psychology: General, 143*, 2020–2045. http://dx.doi.org/10.1037/xge0000014.