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Cognitive Psychology

On the Interplay Between Stimulus-driven and Goal-directed Processes in the Decision to Fight or Flee

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Traditional emotion theories assume that stimulus-driven processes are responsible for early emotional action tendencies and that goal-directed processes step in at a later stage to implement or correct these action tendencies. In contrast to this, a recent, goal-directed theory proposes that goal-directed processes operate in parallel with stimulus-driven processes at an early stage, that they enter in competition with the stimulus-driven processes, and that they defeat stimulus-driven processes in most cases. Recent studies found evidence that goal-directed processes can indeed determine early action tendencies, but they did not examine what happens when these processes enter in competition with stimulus-driven processes. The aim of the current study was to examine whether goal-directed processes can also determine early action tendencies when they are put in competition with a stimulus-driven process. To test this, we first conducted two experiments (N = 59; N = 40) to establish the operation of a stimulus-driven process and we conducted a third experiment (N = 103) in which the stimulus-driven process was pitted against a goal-directed process. Early action tendencies were measured with implicit measures (i.e., compatibility tasks). The first two experiments provided support for the operation of a stimulus-driven process in which negative valence elicits a tendency to fight. The third experiment suggested that the goal-directed process indeed operated in parallel with the stimulus-driven process, but not that the goal-directed process was able to literally defeat the stimulus-driven process.

Emotion theories have long tried to explain emotional behaviors that fall in the categories of "fight" (aggression) and "flight" (withdrawal, avoidance). Traditional emotion theories qualify as reactive theories in that they put forward stimulus-driven explanations for emotional behaviors. The idea is that emotional behavior is caused by a fixed link between specific stimulus features (as evaluated) and specific action tendencies. Appraisal theories, for instance, propose that stimuli appraised as goal incongruent (e.g., an enemy threatens the goal to be safe) and easy to control (e.g., you have good behavior options to alleviate the threat) lead to the tendency to fight whereas stimuli appraised as goal incongruent and difficult to control (e.g., you have a limited scope of action to reach safety) lead to the tendency to flee (Ellsworth & Scherer, 2003).

A recent emotion theory proposed by Moors (2017a; Moors et al., 2017; Moors & Fischer, 2019) qualifies as an instrumental theory in that it puts forward a goal-directed explanation for emotional behaviors. This theory agrees with appraisal theory that the tendencies to fight and flee stem from a discrepancy between a stimulus and a goal (e.g., safety). Such a stimulus-goal discrepancy corresponds to what appraisal theory calls goal incongruence. The goal-directed theory differs from appraisal theory, however, in that it proposes that the selection between the tendencies to fight and flee does not depend on an appraisal of the ease/difficulty to control the stimulus in general (i.e., whether the person sees any/no options to repair the discrepancy), but rather on the expected utilities of the specific behaviors of fighting and fleeing to reduce the stimulus-goal discrepancy. The tendency to fight vs. flee is activated if fighting vs. fleeing has the highest expected utility, that is, the highest expectancy for reaching the person's goals or needs. According to this explanation, if an enemy threatens one's goal for safety, the tendency to fight is activated if one expects that fighting is most likely to bring safety and the tendency to flee is activated if one expects that fleeing is most likely to bring safety.

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At first sight, this explanation might seem similar to the one offered by appraisal theory, but on closer inspection, it is different in a subtle but important way. The difference becomes clear when considering a case in which a stimulus is easy to control by fleeing from it, which means that fleeing has a high expectancy. In this case, appraisal theory predicts that a tendency to fight is activated (because control is high) whereas the goal-directed theory predicts that a tendency to flee is activated (because fleeing has a high expectancy). The two theories also make different predictions for the case in which a stimulus is difficult (or impossible) to control. Appraisal theory predicts a tendency to flee (because control is low) whereas the goal-directed theory predicts a tendency to be passive (because there are no action options with a sufficiently high expectancy; Moors et al., 2019).

The stimulus-driven and goal-directed processes central in reactive and instrumental theories differ in the content of the mental representations involved. A stimulus-driven process contains an association between a representation of a stimulus or stimulus features (S; e.g., goal incongruent and difficult to control) and a representation of a behavior or action tendency (R; e.g., fight). If a stimulus activates this association, it may translate into overt behavior. In short, according to a stimulus-driven explanation, a behavior is elicited if a representation of the stimulus features associated with the representation of the behavior is activated. A goal-directed process, on the other hand, selects a behavior based on representations of the expected utilities of behavior options. The expected utility of one behavior option is a function of the subjective value of the outcomes of the behavior and the expectancies that the behavior reaches these outcomes (Savage, 1954). If several behavior options are available, their expected utilities are compared and the behavior option with the highest expected utility is selected. In short, according to a goal-directed explanation, a behavior is elicited if its expected utility is higher than the expected utilities of other available behavior options.

In the goal-directed theory (Moors, 2017a, 2017b; Moors et al., 2017), the behavior selection process can be embedded in a cycle, where it is preceded by a comparison of a stimulus with a person's goals. If the stimulus is discrepant with a goal, the person has three options to reduce the discrepancy: (a) select a behavior (as described above) to align the stimulus with the goal (i.e., assimilation), (b) change the goal (i.e., accommodation), or (c) bias the interpretation of the stimulus (i.e., immunization; see Brandtstädter & Greve, 1994). If a behavior is selected, the tendency or intention to engage in this behavior is activated, which is further implemented in overt behavior. The outcome of this behavior is in fact a new stimulus that is again compared to the goal. The cycle is repeated until no discrepancy remains or another stimulus-goal discrepancy takes priority.

Although traditional emotion theories put forward a stimulus-driven process as the mechanism for the initial, emotional action tendency, they do allow goal-directed processes to play a role either in the implementation of this action tendency into a more concrete action tendency or action program (i.e., planning) or in the correction of this action tendency in line with certain goals (i.e., regulation; Moors, 2022). Thus, the initial tendency to fight can be implemented in a physical or verbal attack, or it can be suppressed to avoid retaliation. This view about the interplay between stimulus-driven and goal-directed processes is known as the default-interventionist view. Stimulus-driven processes are considered to be more automatic, and hence faster, than goal-directed processes (Moors, 2016). This is why it is assumed that stimulus-driven processes are the default process, which starts early, and that goal-directed processes can intervene, but only at a later point in time.

The goal-directed theory of emotions (Moors, 2022) proposed a parallel-competitive view regarding the interplay between stimulus-driven and goal-directed processes. Here, it is assumed that both stimulus-driven and goal-directed processes can operate automatically and hence that they operate at an early stage. This implies that they can occur concurrently and that they compete with each other to determine behavior. The theory, moreover, assumes that goal-directed processes should win this competition in most cases because goal-directed processes are more likely to lead to optimal behaviors. Stimulus-driven processes, on the other hand, are assumed to determine behavior only in exceptional cases, for example, when different behavior options (e.g., fight and flee) have the same expected utility. In this case, the goal-directed processes may block each other so that they do not enter in competition with any activated stimulus-driven process. This allows the stimulus-driven process to determine the behavior.

In sum, traditional emotion theories with a default-interventionist view suggest that stimulus-driven and goal-directed processes operate sequentially, with the stimulus-driven one starting first and the goal-directed one kicking in later. The goal-directed theory with its parallel-competitive view, on the other hand, suggests that both processes operate simultaneously, that they compete with each other to determine the behavior, and that the goal-directed process wins the competition most of the time. Thus, both types of theories hold a different process responsible for early action tendencies: Traditional theories assume that early action tendencies are always determined by a stimulus-driven process whereas the goal-directed theory assumes that early action tendencies are predominantly determined by a goal-directed process.

Recent studies examined and found evidence for the idea that goal-directed processes can indeed cause early emotional action tendencies as predicted by the goal-directed theory (e.g., M. Fischer et al., 2020; Moors et al., 2019). For instance, Moors et al. (2019) developed a multiple-trial computer game in which they examined whether early action tendencies were caused by (a) a stimulus-driven process in which a goal-incongruent stimulus that is easy/difficult to control is associated with the tendency to fight/flee or (b) a goal-directed process in which a goal-incongruent stimulus or discrepancy leads to the tendency to fight/flee if fighting/fleeing has the highest expectancy to undo the discrepancy. In this game, participants had to earn money as street musicians. On some trials, they en-

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countered a goal-incongruent stimulus or discrepancy in the form of thieves that attempted to steal money. The stimulus-driven process was induced by manipulating the general ease/difficulty to control the thief (i.e., prevent the theft): Two thieves were easy to control in that participants had a behavior option at their disposal to prevent the theft and one thief was difficult (in fact, impossible) to control in that no behavior option was available. The goal-directed process was manipulated partially independently from the stimulus-driven process by manipulating the expectancies of specific fight and flee behaviors in defeating the thief. Among the thieves that were easy to control, one could be defeated by fighting against him (i.e., high expectancy of fighting) whereas the other could be defeated by fleeing from him (i.e., high expectancy of fleeing). The thief that was difficult to control could not be defeated by fighting nor by fleeing (i.e., zero expectancy of fighting and fleeing). Early action tendencies were measured by registering motor evoked potentials (MEPs) that were enhanced by single-pulse transcranial magnetic stimulation (TMS) administered 400 ms post-stimulus onset. The MEPs were registered from effector muscles that had been associated with fight and flee behaviors during a prior training phase. By comparing the MEPs of the fight and flee effectors, the researchers could infer the action tendency that was elicited in each condition (i.e., if MEPs were higher in the fight/flee effector than the flee/fight effector, they could infer that participants had the tendency to fight/flee). The predictions were that if the stimulus-driven process determined the action tendencies, the two easy-control conditions would show a tendency to fight and the difficult-control condition a tendency to flee. If a goal-directed process determined the action tendencies, on the other hand, the easy-control-flee condition should show a tendency to flee (instead of a tendency to fight) and the difficult-control condition a tendency to be passive (instead of a tendency to flee). The results provided preliminary evidence that the early tendencies to fight and flee were indeed determined by the goal-directed process and not by the stimulus-driven process, which is in line with the predictions of the goal-directed theory.

The study, however, did not allow examining whether the goal-directed process had literally competed with and won against the stimulus-driven process because the study only provided evidence for the operation of a goal-directed process and not for the operation of a stimulus-driven process. It was therefore uncertain whether a stimulus-driven process was present in the first place. Hence, this study cannot rule out the possibility that goal-directed processes were only able to determine early action tendencies if there was no stimulus-driven process present. The aim of the current study was to examine whether goal-directed processes can also determine early action tendencies if they have to compete against a stimulus-driven process. We investigated this by first seeking evidence for the existence of a stimulus-driven process and by then pitting this stimulus-driven process against a newly installed goal-directed process. We conducted a first experiment to assess the existence of a stimulus-driven process proposed by appraisal theories. As we found unexpected results, a second experiment was done to test the existence of an alternative stimulus-driven process that fitted with the results of the first experiment. In a third experiment, we tested whether this stimulus-driven process could be defeated by a newly installed goal-directed process.

Experiment 1

In the first experiment, we investigated the same stimulus-driven process as Moors et al. (2019) in which a goal-incongruent and easy/difficult to control stimulus elicits a tendency to fight/flee. There is some evidence for the existence of this process, but the majority of this evidence is based on self-reports (e.g., A. H. Fischer & Roseman, 2007; Frijda et al., 1989) and experimental evidence is scarce (Scherer & Moors, 2019). Self-reports are problematic because they may only capture the beliefs that people have about possible causes of their action tendencies rather than the actual underlying mechanisms (Nisbett & Wilson, 1977; Robinson & Clore, 2002). Therefore, the goal of Experiment 1 was to investigate experimentally whether a goal-incongruent stimulus that is easy/difficult to control does indeed elicit the tendency to fight/flee when it is free from competition of a goal-directed process.

We designed an adapted version of the street musician paradigm described above (Moors et al., 2019) in which goal-incongruent stimuli that were easy/difficult to control were presented and in which action tendencies were measured via the facilitation of instructed responses (as is done in stimulus-response compatibility tasks; Kornblum et al., 1990). The experiment consisted of a series of trials. The stimulus-driven process was induced as follows: On each trial, participants encountered a goal-incongruent stimulus (i.e., a thief signaling a theft), with a certain degree of controllability: A first thief could be defeated in 100% of the trials (i.e., easy-control condition), a second thief in 50% of the trials (i.e., moderate-control condition), and a third thief in 20% of the trials (i.e., difficult-control condition). We added the moderate level of control for exploratory reasons. Soon after the stimulus presentation, participants were instructed to fight against or flee from the thief. Within each thief condition, fighting and fleeing had the same expected utility. That is, they were equally effective or ineffective to defeat the thief.

We measured the action tendencies that participants had in each condition by comparing the speed and accuracy with which they were able to execute the instructed response in that condition. If in a condition, the instruction to fight was executed faster and with less errors than the instruction to flee, for instance, we inferred that the stimulus in this condition had elicited the tendency to fight, which had subsequently facilitated execution of the instruction to fight.

Based on the stimulus-driven hypothesis that a goal-incongruent stimulus that is easy/difficult to control (S) elicits the tendency to fight/flee (R), the easy-control/difficult-control condition would elicit the tendency to fight/flee, resulting in facilitated execution of the instruction to fight/flee. If in the easy/difficult-control condition, a facilitation

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of fight/flee responses would indeed occur, we would interpret this as evidence that appraisal of the thieves (S) is sufficient to elicit an action tendency (R), which qualifies as a stimulus-driven process, and that activation of this action tendency, in turn, facilitates execution of the same instructed action tendency. According to an alternative explanation of this compatibility effect, however, instructed responses are facilitated, not because they overlap with the action tendency elicited by appraisal of the thieves, but because they have semantic overlap with appraisal of the thieves (Fini et al., 2020; van Dantzig et al., 2009; Zhang et al., 2012). The thief that is difficult to control could facilitate an instructed fight response because this thief and this response share the feature "strong". Likewise, the thief that is easy to control could facilitate an instructed flee response because this thief and this response share the feature "weak". If semantic overlap between appraisals of stimuli and instructed responses would be responsible for the predicted compatibility effect, occurrence of such an effect would not guarantee that appraisals of stimuli (the thieves) elicited an action tendency in the first place, and hence it would not provide evidence for the operation of a stimulus-driven process.

In an attempt to test this alternative explanation, we counterbalanced whether the features strong and weak were used to describe either the thieves or the participant. In one framing group, thieves were described as weaker than the participant (in the easy-control condition), equally strong or weak as the participant (in the moderate-control condition), and stronger than the participant (in the difficult-control condition). In another framing group, the participants were described as stronger than the thieves (in the easy-control condition), equally weak or strong as the thieves (in the moderate-control condition), and weaker than the thieves (in the difficult-control condition). If our framing manipulation would influence the effects, this should give an indication of whether the results can (at least partly) be explained via a semantic matching mechanism.

Method

Sample and design. Sixty students participated in the study in return for course credits and the money they won in the game. All participants gave written informed consent. One participant was excluded because she failed to give a response before the response deadline in 24% of the trials in the test phase. This resulted in a final sample of 59 participants (23 men, 7 left-handed, M_{age} = 20). This sample size allows detecting a three-way interaction effect with a minimal effect size of $\eta^2_p = 0.08$ if $\alpha = 0.05$ and $\beta = 0.8$ according to a sensitivity analysis using MorePower 6.0.4 (Campbell & Thompson, 2012). The experiment had a mixed design with the within-subjects factors control (easy-control, moderate-control, difficult-control) and response cue (fight, flee) and the between-subjects factor framing (thief-centered, participant-centered). Additionally, we also counterbalanced the hand with which participants executed the fight and flee response. Half of the participants used the right hand for the fight response and the left hand for the flee response (right-fight-left-flee condition). For the other half, the mapping was reversed (left-fight-right-flee condition). The experiment was approved by the local ethics committee of Ghent University. In the three experiments, we report all manipulations, measures, and exclusions. The anonymized dataset and syntax code used for the analysis in all three experiments are available on OSF: https://osf.io/at45p/.

Materials and procedure. Participants were seated in front of a computer with two keyboards. They were informed that they would play a game in which they would try to earn money as a street musician and that they would receive this money at the end of the game. Throughout the game, a street scene was shown on the screen with a hat filled with money lying on the pavement. Nine different avatars composed of a black standing silhouette and a face could appear in this street scene. Five of the avatars just walked by (the passers-by), three stole one euro (the thieves), and one gave two euros (the giver). The face stimuli for these avatars were selected from the Radboud face database (Langner et al., 2010) and were rated as neutral with regard to criminal look and physical strength. The face stimuli used for the three thief avatars were counterbalanced between participants. The experiment was programmed with Affect 4.0 (Spruyt et al., 2010) and consisted of (a) a "stimulus-outcome" practice phase in which participants were introduced to the avatars and the outcomes resulting from the encounters with the avatars, (b) a "hand-response" practice phase in which participants learned which hand to use for fighting and which hand to use for fleeing, (c) a "stimulus: response-outcome" practice phase in which participants learned how much control they had over the thieves by fighting or fleeing, and (d) a test phase. We discuss these phases in more detail below.

"**Stimulus-outcome" practice phase**. In this phase, participants learned which avatars (stimuli) were passers-by (leading to a neutral outcome), which ones were thieves (leading to a negative outcome), and which one was the giver (leading to a positive outcome). The phase consisted of two blocks in each of which participants randomly encountered each passer-by once, each thief three times, and the giver either three times (in the first block) or two times (in the second block). The ITI was set to 2000 ms on average (± 500 ms) for the whole experiment. Each trial started with the presentation of an avatar. If the avatar was a passer-by, he disappeared again after 2300 ms and the trial was terminated. If the avatar was a thief, he crouched at 2300 ms after stimulus onset for a duration of 1500 ms, he moved his hand to the hat while a money-taking sound was played (this animation took 200 ms), and he disappeared again. After this, the message "-1" with an arrow pointing downwards and the new money total in the hat was presented for 4000 ms after which the trial was terminated. If the avatar was the giver, he crouched at 2300 ms after stimulus onset for a duration of 1500 ms and moved his hand to the hat while a money-dropping sound was played (this animation took 200 ms). Then the message "+2" with an arrow pointing upwards was displayed for 4000 ms and the trial was terminated. The hat contained 25 euro at the beginning

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of this phase and was reduced to 17 euro at its end. Before moving to the next phase, participants were shown a lineup of all avatars and were asked to identify the thieves. This was done to make sure that participants learned which of the avatars led to a negative outcome. If participants made an error, an error message appeared, and participant received an additional trial to correctly identify the thieves.

"Hand-response" practice phase. In this phase, participants learned which hand to use to fight against and which hand to use to flee from the thieves. Participants practiced each of these responses two times in a block of four trials in total. The sequence of events in each trial was similar to that in the trials of the previous practice phase. Each trial started with the presentation of a completely black silhouette and participants were instructed to respond in line with the auditory response cues "vecht" (Dutch for fight) or "vlucht" (Dutch for flee), which were delivered through headphones at 300 ms after trial onset. Participants had two keyboards to execute these responses, one positioned closer to the screen, labeled with the word "vecht" and another one positioned in front of them, labeled with the word "vlucht". Depending on the hand-response mapping condition, the upper keyboard was shifted to the right/left, so that participants could fight with their right/left hand and flee with the other hand. This arrangement allowed counterbalancing the hand with which the fight and flee response was executed while ensuring that the hand further away from the participant was always used to fight and the hand closer to the participant was always used to flee.[1] If participants pressed the fight key after hearing the fight instruction, a fist hitting the thief appeared on the screen for 2000 ms while a punching sound was played until the black silhouette disappeared. If participants pressed the flee key after hearing the flee instruction, a hand grabbed the hat and pulled it away from the thief (this animation took 200 ms), and a running-with-money sound was administered for 2000 ms until the black silhouette disappeared. If participants did not respond until 2000 ms after stimulus onset, the message "TOO LATE!" was presented for 3000 ms. If participants responded incorrectly (e.g., pressed the fight key after a flee instruction), the message "ERROR!!!" was presented for 3000 ms and no response animation was shown. The trials were terminated after registration of a correct response or after the presentation of the delay or error message. During this phase, no money could be won or lost.

"Stimulus: response-outcome" practice phase. In this phase, participants learned that one thief was easy to control (easy-control condition), another thief was neither easy nor difficult to control (moderate-control condition), and still another thief was difficult to control (difficult-control condition). Participants were instructed that correct fight and flee responses were effective to defeat the thief and prevent him from stealing in 100% of the trials in the easy-control condition, in 50% of the trials in the moderate-control condition, and in 20% of the trials in the difficult-control condition. In addition, depending on the framing condition, either the strength of the thieves or the strength of the participants was described. In the thief-centered framing group, the easy to control thief was described as weaker than the participant, the moderately controllable thief as equally weak or strong as the participant, and the difficult to control thief as stronger than the participant. In the participant-centered framing group, the participant was depicted as stronger than the easy to control thief, as equally strong or weak as the moderately controllable thief, and as weaker than the difficult to control thief.

The phase consisted of 12 trials in which each of the three thieves was presented twice with the fight instruction and twice with the flee instruction. In the easy-control condition the responses were always effective, in the moderate-control condition they were effective in half of the trials, and in the difficult-control condition they were never effective[2]. The sequence of events in each trial was the same as in the hand-response practice phase except that now thieves had again faces (instead of completely black silhouettes), the effectiveness of correct responses depended on the identity of the thief, and the thieves always stole money if participants responded incorrectly or late. For incorrect responses, the error message appeared. For late responses, no delay message was displayed. In this phase, money could again be won or lost. Participants retained 11 euro at the end of this phase if all given responses were timely and correct. Finally, participants had to indicate in a lineup of the three thieves, which thief was able to steal money in 0% (easy-control condition), in 50% (moderate-control condition), or in 80% of the cases (difficult-control condition) given a correct response.

Test phase. In the test phase, all avatars (passers-by, thieves, and giver) appeared. The phase consisted of a total of 368 trials presented in random order and grouped into four blocks. In each block, each of the five passers-by appeared 4 times, each of the three thieves appeared 20 times, and the giver appeared 12 times. Participants were instructed to fight in half of the trials and to flee in the other half of the trials (trials were randomly intermixed). The sequence of events in each thief trial was the same as in the previous practice phase (see Figure 1). In passers-by and

1 We opted for this set-up because it ensured some resemblance of the fight and flee responses in our study with natural fight and flee responses (fighting is directed forward and fleeing backward), thereby limiting the number of trials required to establish the meaning of the fight and flee responses in the hand-response practice phase.

2 In the difficult-control condition, the actual effectiveness of the responses was lower than the instructed effectiveness. The reason for this was that we could not balance a higher effectiveness equally between responses due to the limited number of practice trials. This mismatch might have caused some confusion, potentially resulting in longer RTs in the difficult-control condition. We think that this potential confound was negligible as it would have worked in the opposite direction of the observed effect (i.e., smaller RTs in the difficult-control condition).

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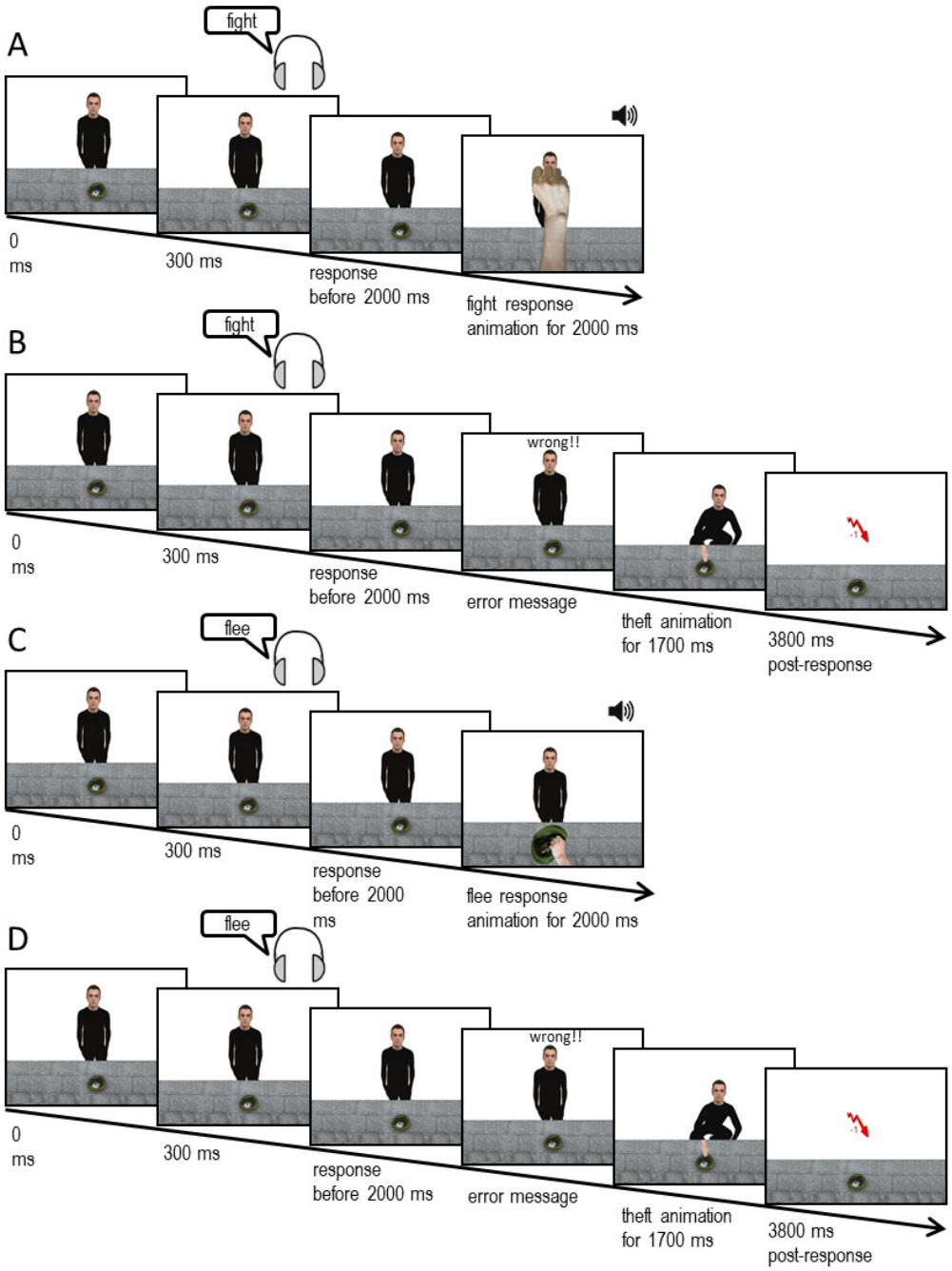

Figure 1. Procedure of the thief trials in the test phase of Experiment 1 in which participants were instructed to fight (A/B) or to flee (C/D) and in which participants executed a correct response before the response deadline (A/C) or a wrong response (B/D). Trials started with the appearance of a thief at 0 ms and the response instruction was given at 300 ms. If participants executed a correct response, the fight/flee response animation was presented. If participants executed a wrong response an error message appeared, the theft animation was presented, and the money loss was indicated with an error pointing downwards.

giver trials, participants were told not to execute the instructed response. If they still responded on a giver trial, the giver would not give money but no error message would appear. Reaction times (RT; measured from the onset of the auditory instruction to the response onset) and errors were registered.

At the end of this phase, pictures of the giver and the thieves were presented in random order and participants evaluated them on strength, valence, and criminal look on a visual analog scale from "very weak"/"very negative"/"not at all criminal" (scored as 0) to "very strong"/"very positive"/"very much criminal" (scored as 100). These ratings were collected mainly for exploratory purposes and most of them are therefore only reported in Supplementary Materials. After these evaluations, participants were informed about the amount of money they won in the game, and they were thanked and debriefed.

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Results

Manipulation checks. Most participants (80%) correctly discriminated the thieves from the other avatars in the "stimulus-outcome" practice phase (12% of the participants made one or two mistakes, 8% made three or more mistakes). When practicing the fight and flee responses in the "hand-response" phase, participants made a mistake in on average 2% (*SD* = 7%) of the trials. Most participants (76%) also correctly indicated which thief stole money in either 0%, 50%, or 80% of the cases in the "stimulus: response-outcome" practice phase (20% of the participants made one mistake, 4% made two mistakes). In sum, participants successfully learned to distinguish the avatars leading to a negative, positive, or neutral outcome, how to fight and to flee, and which thieves were easy, neither easy nor difficult, and difficult to control.

RTs and errors. We only analyzed the RTs and error percentages from the thief trials in the test phase. We discarded trials on which no response was given before the response deadline of 2000 ms (0.27%) and trials on which RTs were below 150 ms (0.02%). For the analyses of the RTs, we also discarded trials on which participants made an error (0.01%). Mean RTs and mean error percentages and their standard deviations are reported in Table 1. Counterbalancing the hand-response mapping did not affect the hypothesized RT and error percentage effects. Therefore, data were collapsed across this factor.

We conducted a 3 x 2 x 2 mixed-model ANOVA on the RTs with the within-subjects factors control (easy-control, moderate-control, difficult-control) and response cue (fight, flee) and the between-subjects factor framing (thief-centered, participant-centered). We obtained an effect of control, $F(2, 114) = 10.16$, $p < .001$, $\eta^2_p = .15$, an effect of response cue, $F(1, 57) = 73.69$, $p < .001$, $\eta^2_p = .56$, and an interaction between control and response cue, $F(2, 114) = 5.43$, $p = .006$, $\eta^2_p = .09$ (see Figure 2). No other significant effects were obtained, all Fs < 0.87. Planned comparisons on the significant interaction effect indicated that participants were faster to fight against than to flee from the easy-control thief, $t(57) = -5.66$, $p <. 001$, 95% CI [-63.49, -30.31], $d_z = 0.74$, from the moderate-control thief, $t(57) = -5.30$, $p <. 001$, 95% CI [-58.11, -26.23], $d_z = 0.69$, and from the difficult-control thief, $t(57) = -9.30$, $p <. 001$, 95% CI [-83.52, -53.93], $d_z = 1.21$. In addition, participants were faster to fight against the difficult-control thief than against the moderate-control thief, $t(57) = -4.60$, $p <. 001$, 95% CI [-49.23, -14.88], $d_z = 0.60$, and faster to fight against the difficult-control thief than against the easy-control thief, $t(57) = -3.87$, $p =. 001$, 95% CI [-51.06, -11.33], $d_z = 0.50$. Note that all paired comparisons reported in this paper were corrected using a Bonferroni adjustment for multiple testing.

A 3 x 2 x 2 mixed-model ANOVA (with Huynh-Feldt correction for violation of sphericity)[3] on the error percentages with the factors control, response cue, and framing yielded only an effect of control, $F(1.76, 100.55) = 4.57$, $p = .016$, $\eta^2_p = .07$. No other significant effects were revealed, all Fs < 3.35. Pairwise comparisons indicated that participants made more errors with the difficult-control thief than with the moderate-control thief, $t(57) = 2.93$, $p = .014$, 95% CI [0.12, 1.32], $d_z = 0.38$.

Taken together, the RT data indicate that an easy/difficult to control stimulus did not elicit a tendency to fight/flee, but that the tendency to fight was increasingly facilitated with a decreasing amount of control over a goal-incongruent stimulus. These results were not replicated with the error data.

Exploratory analysis. For exploratory purposes, we also examined with a repeated-measures ANOVA whether the manipulation of control changed the perceived valence of the thieves. This ANOVA yielded an effect of control, $F(2,116) = 16.38$, $p < .001$, $\eta^2_p = .22$. Pairwise comparisons revealed that the difficult-control thief ($M = 16.44$, $SD = 19.60$) was rated as more negative than the moderate-control thief ($M = 27.20$, $SD = 22.26$), $t(57) = -3.55$, $p = .002$, 95% CI [-18.24, -3.29], $d_z = 0.46$ and also more negative than the easy-control thief ($M = 35.02$, $SD = 21.91$), $t(57) = -5.24$, $p < .001$, 95% CI [-27.31, -9.84], $d_z = 0.68$. In sum, these results suggest that a decrease in the controllability of stimuli was associated with an increase in their negativity.

Discussion

In Experiment 1, we experimentally investigated whether a goal-incongruent and easy/difficult to control stimulus elicits a tendency to fight/flee. We did this by presenting participants with goal-incongruent stimuli, which differed in the degree to which they could be controlled and by assessing the action tendencies that they elicited based on the speed and accuracy with which instructed responses could be executed. The RT data indicated a linear relationship opposite to the predictions of the stimulus-driven process proposed by appraisal theory: Thieves who were more difficult to control led to a stronger facilitation of the tendency to fight.

The error data did not yield the same results as the RT data for the main research question. The error percentages were, however, very low, which can be explained by the fact that we used a very generous response deadline (i.e., 2000 ms) and that participants were punished for making mistakes (i.e., they lost money). These low percentages suggest that the participants traded speed for accuracy, so that the effect was mainly manifested in the RTs. Because of the low number of error percentages, we cannot draw meaningful conclusion from the error results.

3 In all experiments, the distribution of the error percentages seemed to deviate from a normal distribution. Analyses with log-transformed error percentages yielded results descriptively similar results to the reported results.

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Table 1. Means and standard deviations (in parenthesis) of the RTs and error percentages in Experiment 1, 2, and 3

	Experiment 1					
	Thief-centered			Participant-centered		
	Easy-control	Moderate-control	Difficult-control	Easy-control	Moderate-control	Difficult-control
RTs						
Fight	584.19 (108.75)	586.96 (112.41)	549.52 (100.76)	561.08 (100.73)	560.04 (100.65)	533.37 (99.83)
Flee	635.14 (128.31)	625.30 (129.47)	625.25 (117.93)	603.94 (88.90)	606.04 (105.43)	595.08 (92.00)
Errors						
Fight	1.65 (2.63)	1.30 (2.29)	1.65 (2.71)	1.10 (2.06)	0.94 (1.58)	1.82 (2.69)
Flee	1.22 (2.09)	0.88 (1.23)	1.22 (1.61)	1.42 (3.81)	1.20 (1.76)	2.49 (2.93)
	Experiment 2					
	Mildly negative	Moderately negative	Highly negative			
RTs						
Fight	574.88 (117.32)	562.61 (116.65)	540.83 (118.60)			
Flee	595.51 (128.26)	594.16 (125.53)	598.70 (131.26)			
Errors						
Fight	3.60 (4.71)	1.38 (2.26)	1.63 (3.03)			
Flee	1.19 (1.88)	1.88 (2.70)	2.63 (3.80)			
	Experiment 3					
	Equal expectancies			Unequal expectancies		
	Mildly negative	Moderately negative	Highly negative	Mildly negative	Moderately negative	Highly negative
RTs						
Fight	549.08 (82.36)	550.19 (93.81)	552.44 (89.62)	589.82 (107.89)	590.83 (105.72)	597.30 (117.61)
Flee	565.60 (89.37)	571.86 (88.02)	567.30 (92.01)	593.15 (104.80)	581.85 (97.96)	589.89 (105.68)
Errors						
Fight	1.33 (2.17)	1.08 (2.25)	1.18 (1.45)	0.56 (1.11)	0.77 (1.95)	0.58 (1.17)
Flee	0.93 (1.80)	0.78 (1.69)	0.78 (2.26)	0.38 (1.04)	0.43 (0.96)	0.19 (0.68)

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Furthermore, we also investigated whether the facilitation of certain responses can (at least partly) be explained by a semantic matching mechanism. To do this, we counterbalanced whether the participants (in relation to the thieves) or the thieves (in relation to the participant) were described as strong, equally strong or weak, or weak. The analyses of the RTs and the percentages of errors showed that this manipulation did not affect the facilitation of the responses. Therefore, it seems unlikely that the results can be explained by a semantic matching mechanism.

The RT data show that a decrease in the controllability of the thieves led to a stronger facilitation of the tendency to fight. These results do not support the operation of the stimulus-driven process suggested by appraisal theories in which a decrease in the controllability of a stimulus leads to a switch from a tendency to fight to a tendency to flee. The results are rather compatible with the opposite stimulus-driven process in which a stimulus that is difficult to control elicits a tendency to fight. Previous support for the existence of this process comes from experimental studies showing that participants acted more aggressively when confronted with noise that was more difficult to control (e.g., Donnerstein & Wilson, 1976; Warburton et al., 2006). It could be argued, however, that a decrease in the controllability of stimuli also implies an increase in negative valence. This is corroborated by the exploratory analysis in Experiment 1, which revealed that less controllable thieves were evaluated as more negative. These results point at the operation of an alternative stimulus-driven process in which negative valence elicits the tendency to fight. This fits with Berkowitz's (1989; Berkowitz & Harmon-Jones, 2004) version of the frustration-aggression hypothesis (Dollard et al., 1939), which states that negative valence is sufficient to elicit aggressive tendencies. Accordingly, stimuli that are goal-incongruent (i.e., frustrating) or difficult to control may only promote aggressive tendencies because or to the extent that they produce negative valence or affect. This suggests that negative valence might have directly led to the tendency to fight in Experiment 1. Experiment 2 was set up to test this hypothesis.

Experiment 2

To test whether negative valence is sufficient to elicit a tendency to fight, we adapted the paradigm of Experiment 1 so that only valence was manipulated but not controllability. In Experiment 2, again three different thieves could appear in the street scene. The valence of the thieves was manipulated by varying the amount of money they stole from the participant. Thieves could be mildly negative, moderately negative, or highly negative. The thieves were moderately easy to control in that both fighting and fleeing from them was successful in 50% of the trials. Based on the stimulus-driven hypothesis that negative valence indeed elicits a tendency to fight, we expected that participants would have a stronger tendency to fight than to flee and that the tendency to fight would get stronger with increasing negativity of the thieves.

In Experiment 2, we no longer created different framing groups because this manipulation did not appear to influence the effects in Experiment 1, which suggests that it was unlikely that the semantic matching mechanism was responsible for the effects. In Experiment 2, a semantic matching mechanism could provide an alternative explanation for our findings provided that the tendency to fight would have a stronger negative valence than the tendency to flee. In that case, the thief could facilitate the fight response because the feature (i.e., valence) overlap between this stimulus and this instructed response would be more substantial than between the highly negative thief and the flee response. Note that the semantic match between stimulus and response in this case also qualifies as an affective match. In order to explore this possibility, participants were asked to rate the valence of the fight and flee responses at the end of the experiment.

Method

Sample and design. Forty participants (10 men, 6 left-handed, M_{age} = 22, 38 students) took part in the study in return for payment (10 euro, augmented with the amount they won in the game). A sensitivity analysis with MorePower 6.0.4 (Campbell & Thompson, 2012) revealed that this sample size allows detecting an interaction effect with a minimal effect size of $\eta^2_p = 0.11$ if $\alpha = 0.05$ and $\beta = 0.8$. All participants gave their written informed consent. The experiment had a 3 x 2 within-subjects design with the factors valence (mildly negative, moderately negative, highly negative) and response cue (fight, flee). Like in Experiment 1, we counterbalanced the mapping between hand (right/left) and response (fight/flight). The experiment was approved by the local ethics committee of Ghent University. The anonymized data and the analysis code are available on OSF: https://osf.io/at45p/.

Materials and procedure. The same materials were used as in Experiment 1. The procedure of Experiment 2 was similar to that of Experiment 1. Participants were again introduced to the different avatars in a "stimulus-outcome" practice phase, their knowledge about the avatars was tested with a lineup at the end of this phase, they practiced the fight and flee response in the "hand-response" practice phase, the elicited action tendencies were assessed in the test phase, and participants completed a similar questionnaire at the end of the experiment. The following procedural differences with Experiment 1 were installed: (1) In the "stimulus-outcome" practice phase, the valence of the thieves was manipulated instead of their controllability. This was done by varying the amount of money the thieves stole. The mildly negative, moderately negative, and highly negative thieves stole one, three, and five euro, respectively. To compensate for the higher amount of money stolen by the thieves in Experiment 2, the money earned from the giver was raised to five euro. The amount of money won or lost on a given thief or giver trial was indicated by pictures of one-euro coins at the end of each of these trials. Furthermore, the passers-by were presented more often to make the task more difficult. As a result, the phase consisted of three blocks in each of which thieves and givers were presented twice and each passerby was presented once (resulting in 13 trials per block). At the end of

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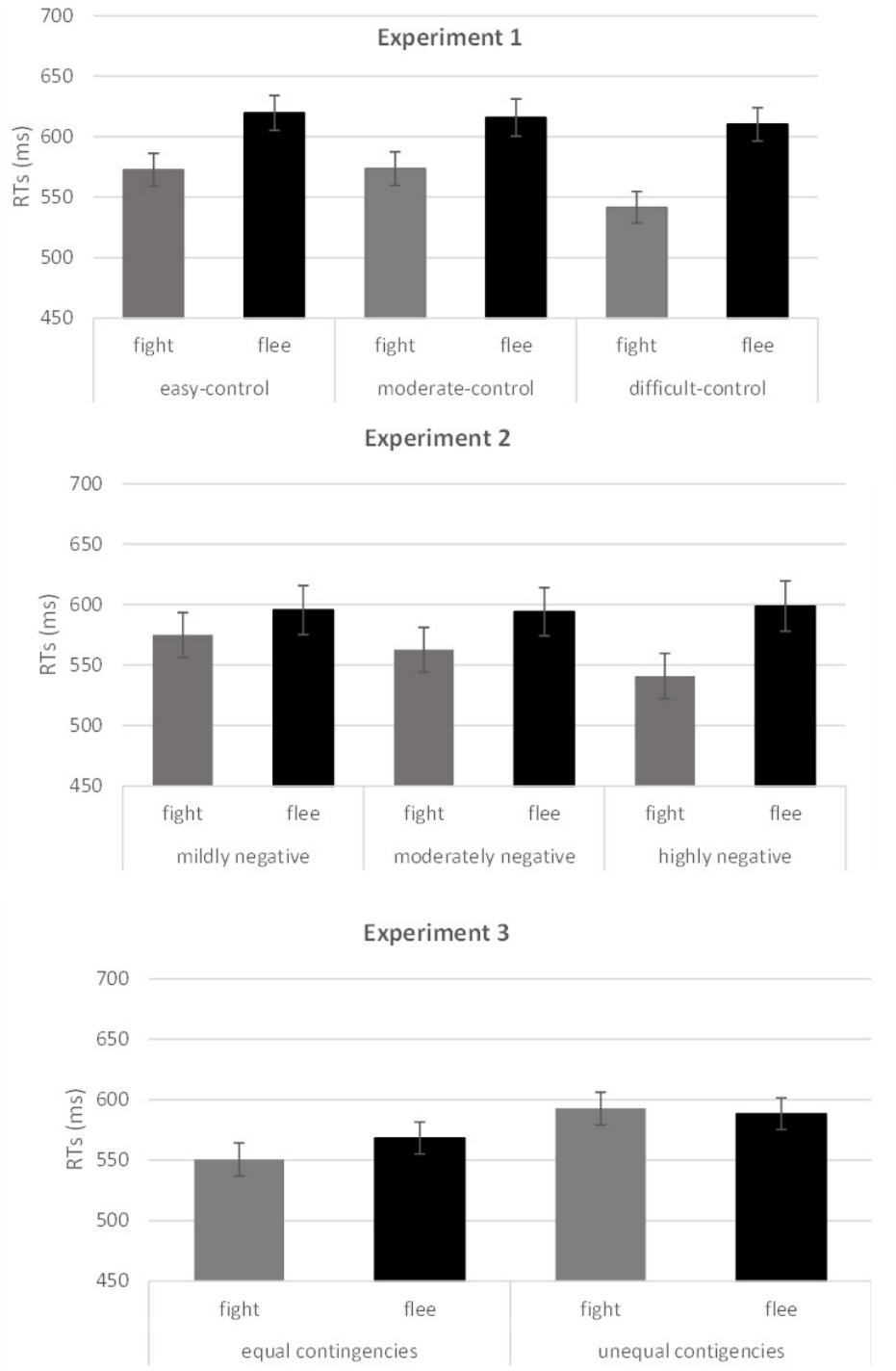

Figure 2. Mean RTs and standard errors per condition in Experiments 1, 2, and 3

this phase, participants not only had to identify the thieves in a lineup with all avatars (passers-by, thieves, and giver), they also received a second lineup with only the thieves, and they had to indicate which thief stole one, three, or five euro. If participants answered all questions without any mistakes, they earned an additional euro. (2) In the "hand-response" phase, the thief avatars were presented instead of a completely black silhouette, every thief appeared twice, the thieves stole money if participants responded incorrectly, and if participants responded correctly, they always prevented the theft. (3) Participants did not complete a "stimulus: response-outcome" practice phase in which they practiced the effectiveness of the fight and flee response to prevent a theft. Instead, they only received verbal information about this effectiveness before the test phase. The reason for this was that the effectiveness did not differ any-

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more between the thieves and was therefore easier to grasp. (4) In the test phase, the giver appeared twice as often in each block in order to raise the amount of money participants could earn. The test phase consisted of 4 blocks with a total of 376 trials (in each block, each of the five passers-by appeared 4 times, each of the three thieves appeared 20 times and the giver appeared 14 times). (5) Performance in all phases, including the "hand-response" practice phase, affected the amount of money in the hat. To compensate for this change, the starting amount was raised to 108 euro so that participants were still able to earn a similar amount of money as in Experiment 1. (6) In the questionnaires at the end of the experiment, participants not only evaluated the valence and the strength of the thieves but also the satisfaction felt from and the justifiability of hitting a thief as well as the valence of the responses. For these evaluations visual analog scales were used with the endpoints "very negative"/"very weak"/'very unsatisfactory"/"very unjustified" (scored as 0) to "very positive"/"very strong"/'very satisfactory"/"very justified" (scored as 100). The strength of the thieves, the satisfaction from and the justifiability of hitting a thief were mainly collected for exploratory purposes and are therefore only reported in the Supplementary Materials. The criminal look of the thieves was no longer assessed.

Results

Manipulation check. In the "stimulus-outcome" phase, almost all participants (92.5%) correctly discriminated the thieves from the passers-by and from the giver (5% made one mistake; 2.5% made two mistakes) and also almost all participants (92.5%) indicated correctly which thief stole one, three, or five euro (7.5% made one mistake). The amount of money the thieves stole influenced how negatively they were perceived, as indicated by a repeated-measures ANOVA (with Huynh-Feldt correction for violation of sphericity) on the perceived valence of the thieves, $F(1.67, 65.09) = 8.91$, $p = .001$, $\eta^2_p = .19$. Pairwise comparisons suggested that the highly negative thief was perceived as more negative ($M = 13.43$, $SD = 15.60$) than the moderately negative thief ($M = 21.33$, $SD = 19.02$), $t(39) = 4.03$, $p = .001$, 95% CI [2.99, 12.81], $d_z = 0.64$, and also as more negative than the mildly negative thief ($M = 24.50$, $SD = 16.22$), $t(39) = 3.52$, $p = .003$, 95% CI [3.21, 18.94], $d_z = 0.56$. Furthermore, participants made on average only in 2.5% ($SD = 7.11\%$) of the trials a mistake in the "hand-response" practice phase. In sum, participants learned successfully which outcome to expect from which avatar and how to fight and to flee from the thieves.

RTs and errors. As in Experiment 1, we removed trials without a response before the response deadline of 2000 ms (0.26%) and trials with RTs below 150 ms (0.01%). For the analyses of the RTs, we also removed trials with errors (2.05%). Means and standard deviations of the RTs and error percentages are reported in Table 1. Counterbalancing the hand-response mapping again did not affect the hypothesized effects, therefore the data were again collapsed across this factor.

A repeated-measures ANOVA (with Huynh-Feldt correction for violation of sphericity) on the RTs with the factors valence (mildly negative, moderately negative, highly negative) and response cue (fight, flee) revealed a main effect of valence, $F(2, 78) = 5.54$, $p = .006$, $\eta^2_p = .12$, a main effect of response cue, $F(1, 39) = 37.27$, $p < .001$, $\eta^2_p = .49$, and an interaction between valence and response cue, $F(1.73, 67.38) = 7.53$, $p = .002$, $\eta^2_p = .16$. Planned pairwise comparisons showed that participants were faster to fight than to flee from the mildly negative thief, $t(39) = 2.41$, $p = .021$, 95% CI [3.33, 37.93], $d_z = 0.38$, from the moderately negative thief, $t(39) = 4.15$, $p < .001$, 95% CI [16.17, 46.92], $d_z = 0.66$, and also from the highly negative thief, $t(39) = 6.70$, $p < .001$, 95% CI [40.39, 75.35], $d_z = 1.06$. Furthermore, these comparisons showed that participants were faster to fight against the highly negative thief than against the moderately negative thief, $t(39) = 2.84$, $p = .022$, 95% CI [2.57, 40.991], $d_z = 0.45$, and than against the mildly negative thief, $t(39) = 3.74$, $p = .002$, 95% CI [11.27, 56.83], $d_z = 0.59$. These results suggest that the RT difference between the fight and flee response was the smallest for the least negative condition and linearly increased for the more negative conditions (see Figure 2). In other words, the more negative the opponent, the faster the fight response became relative to the flee response.

A repeated-measures ANOVA (with Huynh-Feldt correction for violation of sphericity)[3] on the error percentages with the factors valence and response cue revealed an interaction between valence and response cue, $F(1.72, 67) = 8.42$, $p = .001$, $\eta^2_p = .18$, as expected based on the stimulus-driven hypothesis under study. No other significant effects were obtained (all Fs < 2.03). Planned pairwise comparisons indicated that participants made more errors when they had to fight against than when they had to flee from the mildly negative thief, $t(39) = 3.25$, $p = .002$, 95% CI [0.91, 3.90], $d_z = 0.51$. Furthermore, these comparisons indicated that participants made more errors when they had to fight against the mildly negative thief than when they had to fight against the moderately negative thief, $t(39) = 3.30$, $p = .006$, 95% CI [0.54, 3.91], $d_z = 0.52$ and when they had to fight against the mildly negative thief than when they had to fight against the highly negative thief, $t(39) = 2.74$, $p = .027$, 95% CI [0.17, 3.77], $d_z = 0.43$. These results are in line with the RT results and corroborate that the fight response is facilitated with increasing negativity of the thief.

Additional analysis. In order to explore whether a semantic matching mechanism could provide an alternative explanation for the effects, we analyzed whether participants perceived the valence of the fight and flee responses differently. A paired-samples t-test showed that participants rated the fight response ($M = 43.50$, $SD = 22.95$) as more negative than the flee response ($M = 57.05$, $SD = 19.01$), $t(39) = 2.38$, $p = .023$, $d_z = 0.38$.

To investigate the potential influence of a semantic matching mechanism further, we examined whether individual differences in valence ratings of the responses predict the facilitation of the responses. Based on the semantic matching account, the more negative the stimuli (i.e., the valence of the thieves), the stronger the facilitation of a

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negatively perceived instructed response. To test this, we conducted a repeated-measures ANCOVA on the RTs with the factors valence and response cue and the differences in valence ratings as a covariate. The results were qualitatively similar to the ones obtained with the ANOVA and the difference in valence ratings did not have a significant effect (see the supplementary materials for detailed results).

Discussion

The aim of Experiment 2 was to examine the existence of a stimulus-driven process in which negative valence elicits a tendency to fight. We adapted the street musician paradigm of Experiment 1 by manipulating the negativity of the thieves in a way that was unconfounded with their degree of controllability and we measured how fast and how correct participants responded when instructed to fight and to flee from these thieves. Both the RT and the error data indicated that a tendency to fight is indeed more facilitated with increasing negativity of the thieves. These results provide support that negative valence can be sufficient to elicit a tendency to fight, in line with the stimulus-driven process proposed by Berkowitz (1989; Berkowitz & Harmon-Jones, 2004).

The additional analysis revealed that participants perceived the fight response as more negative than the flee response. According to a semantic matching account, the more substantial match between the valence of the thieves and the fight response relative to the flee response (i.e., thieves and the instructed response to fight share the feature negative to a greater extent) could have resulted in a stronger facilitation of the fight response with increasing negativity of the thieves (i.e., the stimulus). However, adding individual differences in the valence ratings of the responses as a covariate (in an ANCOVA) did not yield qualitatively different results. This finding reduces the plausibility of the semantic matching mechanism as an alternative explanation for our results.

Experiment 3

The goal-directed theory endorses a parallel-competitive view, which suggests that a goal-directed process can operate already at an early stage and that it will often defeat parallel operating stimulus-driven processes (Moors, 2017a; Moors et al., 2017). Recent studies found evidence that a goal-directed process can indeed determine early action tendencies, but they did not show that it thereby defeated a stimulus-driven process. In the current set of experiments, we wanted to test whether a goal-directed process can indeed defeat a stimulus-driven process. In Experiments 1 and 2, we first tried to induce a stimulus-driven process so that we could pit this stimulus-driven process against a goal-directed process in Experiment 3.

Experiment 1 suggested the existence of a stimulus-driven process in which the difficulty to control a goal-incongruent stimulus elicits a tendency to fight, or alternatively, for the existence of a stimulus-driven process in which the negative stimulus valence elicits a tendency to fight. In Experiment 2, we found support for the latter stimulus-driven process when keeping the controllability of the stimuli constant. Although Experiment 2 does not rule out the possibility that the difficulty to control a stimulus contributes to the tendency to fight over and above its negative valence, it was not the main aim of the first two experiments to figure this out. Instead, the main aim was to induce *a* stimulus-driven process (no matter which one), so that we could examine in Experiment 3 whether it can be defeated by a goal-directed process.

In Experiment 3, we adapted the design of the street musician paradigm of Experiment 2 as follows. We tried to induce a stimulus-driven process by manipulating the valence of the thieves in the same way as in Experiment 2, that is, by varying the amount of money stolen by the thieves. To install a goal-directed process that could be pitted against this stimulus-driven process, we manipulated the expectancies of the fight and flee responses to defeat the thieves (see also Moors et al., 2019) independent of the valence of the thieves. In a first group of participants, the flee response had a higher expectancy (i.e., 100%) to defeat the thieves than the fight response (0%). In this unequal-expectancy group, the goal-directed process should activate the tendency to flee, which is opposite to the tendency to fight activated by the stimulus-driven process. Thus, here we could test the hypothesis of the goal-directed theory that a goal-directed process defeats a stimulus-driven process and determines the resulting action tendency. More specifically, we expected that in this group the flee response would be faster and more accurate than the fight response. In a second group, on the other hand, the expectancies of the fight and the flee responses were equal (50%; as in Experiments 1 and 2). In this equal-expectancy group, we again assumed that the goal-directed processes would not compete with the stimulus-driven process and that the stimulus-driven process could therefore determine the action tendency. More specifically, we expected that in this group the fight response would be faster and more accurate than the flee response and that this difference would grow with an increasing negativity of the thieves. This condition was added to control whether we had successfully induced the stimulus-driven process.

Method

Sample and design. The hypotheses, the measurements, and the planned statistical analyses were preregistered (https://aspredicted.org/fk3bj.pdf). Hundred-fourteen first-year psychology students participated in the experiment in return for course credits or 4 euro (plus the amount won in the game). Due to unforeseen circumstances, the participant pool had six participants less than mentioned in the pre-registration. All participants gave written informed consent. The data of 11 participants could not be analyzed because of technical problems with the experiment program leading to incomplete data. The final sample consisted of 103 participants (18 men, 7 left-handed, 67% < 20 years, 30% 20 - 29 years, 3% > 30 years). This sample size allows detecting an interaction effect with a minimal effect size of $\eta^2_p = 0.047$ according to a sensitivity analysis using MorePower 6.0.4 (Campbell & Thompson,

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2012) with $\alpha = 0.05$ and $\beta = 0.8$. The experiment had a 3 x 2 x 2 mixed design with the within-subjects factors valence (mildly negative, moderately negative, highly negative) and response cue (fight, flee) and the between-subjects factor expectancy (unequal, equal). Participants were randomly assigned to the unequal-expectancy or equal-expectancy group. The hand-response mapping was counterbalanced over participants as in the previous experiments. The experiment was approved by the local ethics committee of Ghent University. The anonymized dataset and the SPSS syntax are available on OSF: https://osf.io/at45p/.

Materials and procedure. We used the same materials as in the previous experiments and valence was manipulated in the same way as in Experiment 2. The following procedural differences with Experiment 2 were installed: First, we again included a "stimulus: response-outcome" practice phase (as in Experiment 1). In this phase, we manipulated the expectancy of the fight and flee responses to prevent a theft. In the unequal-expectancy group, participants were informed that the fight response would be effective in 0% of the thief encounters and the flee response in 100% of the thief encounters. In the equal-expectancy group, participants were informed that the fight and the flee responses would be effective in 50% of the thief encounters. After the instructions, participants experienced these expectancies in a block of 24 trials in which each thief was presented eight times. The sequence of the events in each trial was the same as in the corresponding practice phase in Experiment 1. At the end of this phase, participants were asked to indicate the degree to which fighting/fleeing can prevent the thieves from stealing money on a visual analog scale from "not at all" (scored as 0) to "very much" (scored as 100). Unfortunately, the answers to this question were not recorded correctly due to a mistake in the experiment program. Participants could also lose money in this phase, which is why the starting amount in the hat was raised to 144 euro (compared to 108 euro in Experiment 2).

Second, the "stimulus-outcome" practice phase, the "hand-response" practice phase, and the test phase were the same as in Experiment 2 except that the passers-by were omitted in all phases to shorten the duration of the experiment. As a result of this change, the test phase consisted of four blocks of in total 296 trials (in each block, the three thieves appeared 20 times each and the giver appeared 14 times).

Third, after the test phase, participants evaluated the effectiveness of the fight and flee responses a second time on a visual analog scale from "not at all effective" (scored as 0) to "very much effective" (scored as 100). This time, the answers were recorded correctly. As in Experiment 2, participants also rated the valence of the responses and the valence and strength of the thieves. The satisfaction felt from and the justifiability of hitting a thief were no longer assessed. The strength of the thieves was assessed for exploratory reasons and is therefore reported in the Supplementary Materials. Unfortunately, the same mistake in the experiment program that affected the first assessment of the expectancy ratings also affected the ratings of the response valence so that these were not recorded.

Results

Manipulation check. Almost all participants (99%) correctly discriminated the thieves from the giver and almost all participants (94%) also correctly indicated which thief stole one, three, or five euro (7% made one mistake, 1% made two mistakes, and 1% made more than two mistakes). When practicing the fight and the flee response, participants made a mistake on average in 2% of the trials (SD = 6.56%). This suggests that participants successfully learned which avatars were the thieves and how to fight and to flee from the thieves.

To test whether we manipulated the valence of the thieves successfully, we conducted a repeated-measures ANOVA (with Huynh-Feldt correction for violation of sphericity) on the valence ratings. Results indicated that participants perceived the valence of the thieves indeed differently, $F(1.76, 179.44) = 60.33$, $p < .001$, $\eta^2_p = .37$. Pairwise comparisons showed that participants perceived the highly negative thief ($M = 16.36$, $SD = 17.24$) as more negative than the moderately negative thief ($M = 24.80$, $SD = 15.37$), $t(102) = 6.70$, $p < .001$, 95% CI [5.37, 11.50], $d_z = 0.66$, and as more negative than the mildly negative thief ($M = 31.55$, $SD = 14.98$), $t(102) = 9.32$, $p < .001$, 95% CI [11.22, 19.17], $d_z = 0.92$. They also perceived the moderately negative thief as more negative than the mildly negative thief, $t(102) = 5.54$, $p < .001$, 95% CI [3.79, 9.72], $d_z = 0.55$.

To test whether we manipulated the expectancy of the fight and flee responses successfully, we conducted a mixed-model ANOVA on the expectancy ratings (measured after the test phase) with the factors response (fight, flee) and expectancy group (unequal, equal). A mixed-model ANOVA on the perceived expectancy of the responses revealed an effect of response cue, $F(1, 100) = 200.42$, $p < .001$, $\eta^2_p = .67$, and an interaction between response cue and expectancy group, $F(1, 100) = 123.91$, $p < .001$, $\eta^2_p = .55$, but no effect of expectancy group, $F = 0.06$. Pairwise comparisons revealed that the flee response was perceived as more effective in the unequal-expectancy group ($M = 81.50$, $SD = 19.75$) than in the equal-expectancy group ($M = 52.30$, $SD = 14.70$), $t(101) = 8.44$, $p < .001$, 95% CI [22.34, 36.06], $d_s = 1.67$, whereas the fight response was perceived as less effective in the unequal-expectancy group ($M = 13.96$, $SD = 19.01$) than in the equal-expectancy group ($M = 44.22$, $SD = 14.09$), $t(101) = 9.11$, $p < .001$, 95% CI [23.67, 36.85], $d_s = 1.81$. These comparisons also revealed that the expectancy of the flee response was rated higher than the expectancy of the fight response in the unequal-expectancy group, $t(101) = 18.06$, $p < .001$, 95% CI [60.12, 74.96], $d_z = 1.78$, but surprisingly also in the equal-expectancy group, $t(101) = 2.12$, $p = .037$, 95% CI [0.51, 15.65], $d_z = 0.21$. This suggests that the manipulation was successful in that the expectancies of

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the fight and the flee responses were evaluated differently between groups, but not in that these expectancies also differed in the equal-expectancy group.[4]

RTs and errors. As in the previous experiments, we only analyzed the thief trials from the test phase. In addition, trials with RTs below 150 ms (0.02%) or above 2000 ms (0.21%) were discarded. For the analyses of the RTs, also trials with errors (0.74%) were discarded. Table 1 presents the means and standard deviations of the RTs and the error percentages per condition. Counterbalancing the hand-response mapping did not affect the hypothesized effects in Experiment 3, which is why data were again collapsed across this factor.

A mixed-model ANOVA (with Huynh-Feldt correction for violation of sphericity) on the RTs with the factors valence (mildly negative, moderately negative, highly negative), response cue (fight, flee), and expectancy (unequal, equal) yielded a significant interaction between response cue and expectancy as predicted, $F(1, 101) = 8.72$, $p = .004$, $\eta^2_p = .08$. Planned comparisons on this interaction effect indicated that the RTs were significantly smaller for the fight response than the flee response, $t(101) = 3.33$, $p = .001$, 95% CI [7.17, 28.21], $d_z = 0.33$, in the equal-expectancy group but did not differ in the unequal-expectancy group, $t(101) = 0.83$, $p = .409$, 95% CI [-6.07, 14.78], $d_z = 0.08$ (see Figure 2). The analysis revealed no other significant effects (all Fs < 3.19).

A mixed-model ANOVA on the error percentages with the factors valence, response cue, and expectancy revealed an effect of response cue, $F(1, 101) = 6.32$, $p = .01$, $\eta^2_p = .06$, suggesting that participants made more mistakes when they had to fight than when they had to flee, and an effect of expectancy, $F(1, 101) = 7.53$, $p = .007$, $\eta^2_p = .07$, suggesting that participants in the unequal-expectancy group made less mistakes than participants in the equal-expectancy group[3]. No other significant effects were obtained (all Fs < 1).

In sum, the RT data suggest that the fight and the flee response were facilitated to a similar degree in the unequal-expectancy group and that the fight response was facilitated more than the flee response in the equal-expectancy group. This pattern of results was not replicated in the error data.

Discussion

The aim of Experiment 3 was to pit a goal-directed process against a stimulus-driven process and to test whether the goal-directed process could defeat the stimulus-driven process. To do this, we manipulated the negativity of the thieves via the amount of money the thieves stole and the expectancy of the responses to defeat the thieves. In the equal-expectancy group in which both responses had the same expectancy, we expected that the stimulus-driven process would determine the action tendencies. In the unequal-expectancy group in which fleeing had a higher expectancy than fighting, we expected that the goal-directed process would determine the action tendencies.

In the equal-expectancy group, the tendency to fight was faster than the tendency to flee, which indicates that the tendency to fight was facilitated more strongly than the tendency to flee. This suggests that a stimulus-driven process had determined the action tendencies in this group. The results in this group were similar to the results of Experiment 2 except that in this group the tendency to fight was not facilitated more strongly with an increasing negativity of the thieves. In the unequal-expectancy group, the RTs did not differ between the fight and the flee responses. This suggests that the goal-directed process was not able to defeat the stimulus-driven process, but it still indicates that the goal-directed process must have operated because the fight response was also not faster than the flee response as was the case in the equal-expectancy group.

In both groups the results of the RT data were not mirrored in the error data. But the error percentages were again very low, which makes it difficult to interpret them in a meaningful way. A limitation of this experiment is that the experiment program did not record the valence ratings of the fight and flee responses. Therefore, we could not examine whether a semantic matching mechanism might provide an alternative explanation for the results in the equal-expectancy group.

General discussion

The aim of this research was to test the prediction of the parallel-competitive model that goal-directed processes and stimulus-driven processes operate in parallel and that when they compete, goal-directed processes defeat the stimulus-driven ones and determine the action tendency that is generated. In the first two experiments, we tried to establish the operation of a stimulus-driven process. In Experiment 1, we tested the stimulus-driven process proposed by appraisal theories in which an easy/difficult to control goal-incongruent stimulus leads to a tendency to fight/flee. The results of this experiment, however, did not provide support for such a process. Instead, the results suggested the operation of another stimulus-driven process in which the negativity of a stimulus elicits a tendency to fight. In Experiment 2, we found support for this process. Taken together, the first two experiments provide support for the existence of a stimulus-driven process in which negative valence elicits a tendency to fight.

In Experiment 3, we pitted this stimulus-driven process against a goal-directed process. The results supported the operation of both processes, but not that the goal-directed process was able to defeat the stimulus-driven process. This last finding is not in line with the predictions of the goal-

4 We repeated the analyses on the RT data with a sample including only participants who reported expectancy ratings close to the objective probabilities of the behavior to prevent the theft. These additional analyses yielded descriptively similar results to the results reported for the full sample.

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directed theory, in particular its parallel-competitive view regarding the interplay between these processes. It is assumed that stimulus-driven and goal-directed processes can operate in parallel so that they compete with each other. The competition can proceed either in a winner-take-all or in an additive fashion. In the winner-take-all scenario, the stronger goal-directed process defeats the weaker stimulus-driven process and acts as the sole determinant of the behavior. In the additive scenario, both processes influence the behavior relative to their strength. As the goal-directed theory assumes that goal-directed processes are stronger than stimulus-driven ones, the goal-directed process should also end up determining the behavior.

The findings of Experiment 3 do not fit with a winner-take-all scenario in which the goal-directed process defeats the stimulus-driven process and acts as the sole determinant of the behavior. Indeed, in the unequal-expectancy group, in which both processes compete with each other, the goal-directed process seems to have operated but it did not solely determine the behavior. The findings of this experiment would, however, fit with an *adapted version* of the additive scenario in which the goal-directed process and the stimulus-driven process compete according to their strength but both processes can be *equally strong* so that adding them up results in a zero net effect. In the equal-expectancy group, the stimulus-driven process activated the tendency to fight, whereas the goal-directed processes activated the tendencies to fight and flee to an equal degree and therefore did not enter in competition with the stimulus-driven process, which elicited the tendency to fight, leading to faster fight than flee responses. In the unequal-expectancy group, the stimulus-driven process activated the tendency to fight and the goal-directed process the tendency to flee. If both tendencies were equally strong, adding them up resulted in equally fast fight and flee responses.

We now discuss three potential limitations of our study. A first potential limitation is that in Experiment 3, we could not rule out that a semantic matching mechanism was responsible for the facilitation of the fight response. Therefore, the findings of Experiment 3 are also compatible with a third scenario in which the goal-directed process operated in parallel with a semantic matching mechanism and in which the interplay between them is also additive. In principle, a semantic matching mechanism may facilitate responses, thereby providing an alternative explanation for response facilitation by means of stimulus-driven or goal-directed processes. However, in our studies, the semantic matching mechanism provides only an alternative explanation for the facilitation of the fight response, presumably elicited by the stimulus-driven process, but not for the facilitation of the flee response, presumably facilitated by the goal-directed process. According to this scenario, in the unequal-expectancy group, the semantic matching mechanism facilitated the fight response whereas the goal-directed process activated the flee response and adding them up resulted in equally fast fight and flee responses. In the equal-expectancy group, the semantic matching mechanism again facilitated the fight response whereas the goal-directed processes blocked each other (equal facilitation of fight and flee responses), resulting in faster fight than flee responses.

It is worth noting, however, that the results of an exploratory analysis were not in line with the semantic matching account. If the semantic matching mechanism were at play, one would expect that participants who rated the fight response as more negative would also show a stronger facilitation of fight responses. The exploratory analysis with individual ratings of the valence of fight responses as a covariate did not provide support for such an effect. Nevertheless, if we want to effectively rule out the semantic matching mechanism, we should turn to a method that does not require response instructions to measure action tendencies. Future research could therefore turn to methods in which the action tendencies elicited by the thieves would not require the use of instructed action tendencies, such as the MEPs enhanced by single TMS pulses discussed in the introduction (e.g., Moors et al., 2019).

A second potential limitation of our study is that we cannot rule out the possibility that the patterns of results that we ascribed to a stimulus-driven process in our experiments stem from a goal-directed process instead.[5] Indeed, the process that we identify as a stimulus-driven process involving a negativity-fight link may alternatively be explained by a goal-directed process in which the more negative thief forms a larger discrepancy (compared to the less negative thief) with the goal to make people respect the moral norm that stealing is bad and, as a result, chooses to punish him more to reduce the discrepancy with this goal. If this scenario holds true, the competition in Experiment 3 may have been a competition between two goal-directed processes rather than between a stimulus-driven and goal-directed one. It is worth noting, however, that such a scenario would still be in line with the goal-directed theory but not with traditional emotion theories. This is because the goal-directed theory not only assumes that already at an early stage, goal-directed processes can enter in competition with stimulus-driven processes (if they exist, and the ones that do exist), but also with other goal-directed processes. Traditional emotion theories with a default-interventionist view, on the other hand, do not allow the operation of goal-directed processes at an early stage and therefore also not the competition between them at this stage.

5 We thank an anonymous reviewer for suggesting this alternative explanation of the findings that we attributed to a stimulus-driven process.

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A third potential limitation that critics might raise is that the repeated reinforcement of the flee response in the unequal-expectancy group in Experiment 3 may install a stimulus-driven process between the respective thief and the response to flee. This is because from a traditional dual-process perspective, it is often assumed that stimulus-driven processes are strengthened with repetition. Yet recent findings suggest that repetition may also result in particularly strong expectancies about the outcomes of certain behaviors (Buabang et al., 2023; Van Dessel et al., 2024). In Experiment 3 the repeated reinforcement of the response to flee may not only have installed a stimulus-driven process, but also a goal-directed one with a particularly strong expectancy that fleeing is an effective response. More generally, this means that stable responding as a result of reinforcement is not a good indicator for whether the underlying process is a stimulus-driven or goal-directed one.

In conclusion, the present study did not provide support for a stimulus-driven process in which an easy/difficult to control goal-incongruent stimulus elicits a tendency to fight/flee. Instead, it provided (reasonable) support for a stimulus-driven process in which negative valence (and/or difficulty to control) elicits a tendency to fight. The study also suggested that the goal-directed process operated simultaneously with the stimulus-driven process or a semantic matching mechanism and that their interplay was additive.

Contributions

Conception and design: AM, MF, EvB, EiB, MK
Acquisition of data: EvB, MF
Analysis and interpretation of data: AM, MF, EvB, EiB, MK
Drafted and/or revised the article: MK, MF, EiB, AM
Approved the submitted version for publication: AM, MF, EvB, EiB, MK

Data Accessibility Statement

The preregistration of Experiment 3 is published on AsPredicted.org: https://aspredicted.org/fk3bj.pdf

The datasets and analysis codes of all experiments are available on OSF: https://osf.io/at45p/

The experimental program will be shared upon motivated request.

Conflict of Interest

All authors declare that they have no conflict of interest.

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