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RESEARCH ARTICLE

Predicting where a ball will land: from thrower's body language to ball's motion

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Abstract To predict where a thrown ball will land, an observer may use visual information about its trajectory. However, in addition, the thrower's body language (i.e., body movement and facial expression) may contain useful information that could be used by the observer to understand intention and emotional state. Here, we investigated how observers estimated a ball's landing point thrown by a virtual agent with different amounts of information from body language. In addition, occlusion time was varied to examine how it potentiates the use of body-language information. Results showed that body movement and facial expression carry information about thrower's effort. However, once the ball has left the thrower's hand, advance information on facial expression does contribute to judgments only if consistent with the amplitude of the throw. Moreover, as the occlusion time increases, a stronger influence of the body movement is observed for estimating the landing point. The overriding effect of ball's trajectory availability over body language is discussed.

Keywords Facial expression · Body movement · Landing point estimation · Weighting of information

Introduction

In order to understand the motor action of others, individuals have access to different sources of information, displayed by others' body or the context. In the case of a thrown ball, observers can use different visual cues, displayed by the pitcher's body and face or by the ball trajectory, in order to predict the ball's landing point. In interceptive actions like when a ball is hit or caught in baseball, the player must place his/her hand in the right place at the right time (Peper et al. 1994). While initially, most studies investigated which visual information related to the ball motion was used to intercept the ball (e.g., tau, the ratio of an object's optical size to its instantaneous rate of optical expansion, Lee 1976, or tau-like variables, Bootsma and Oudejans 1993), it seems now widely accepted that there is information beyond what the eyes meet. Other studies demonstrated that, in parallel to the purely visual information, humans may also use internal knowledge about: for instance, gravity (Zago et al. 2004), an object's shape (López-Moliner et al. 2007), its size (López-Moliner et al. 2007; Hosking and Crassini 2011), its velocity or occlusion, (Tijtgat et al. 2010), and trajectory (Hosking and Crassini 2010). Non visual and implicit information learnt through experience helps observers. They benefit from what they know about the environment to sharpen their estimation of ball movement. However, the involvement of cognitive information appears to be inversely proportional to the quantity of visual information that is available to the observer; as the presentation time of the object's trajectory decreases, the influence of

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knowledge increases (e.g., Baurès and Hecht 2011; Bosco et al. 2012).

Here, we studied which knowledge about the launcher's behavior may influence the spatial extrapolation of an object's trajectory. When a ball is thrown, its landing point is determined entirely by the forces that were given by the launcher to the ball and external forces like gravity and air friction. The latter forces correspond to the environmental constraints, which are presumably integrated in the estimation of the vanishing point of a ball (Hubbard 1995). The former forces correspond to the energy generated by the body movement, depending on its kinematics: velocity, movement duration, etc. Hence, the information about these parameters may influence the estimation of ball's landing point. Evidence supporting this assumption comes from Knoblich and Flach (2001). In this study, participants had to predict the dart's landing position by observing videos of a dart throw, in which the dart was hidden. The authors proposed three conditions of movement observation: view of the arm, view of the body without the head, and view of the body and the head. In this latter condition, participants made more accurate prediction. Authors concluded that observers' capacity to predict the consequences of an action becomes more efficient if they accessed a larger part of the action. Importantly, in this experiment, the pitcher's head did not express any emotion.

In addition to the visual information about the throw itself, it is frequently observed that the amount of forces generated by a launcher is accompanied with very specific facial expressions[1]. These facial expressions could be due to substantial physical effort, as well as pain. Epidemiologic studies reported that approximately 20 and 70 % of baseball players have shoulder and elbow pain, respectively (Olsen et al. 2006; Fleisig et al. 2011). A weak launch usually does not lead to strong facial contractions, whereas strong facial contractions can be observed when a strong launch is made. Similarly, facial expressions can be useful not only in social communication, but also in sport. Individuals have specific capacities to rapidly collect information displayed by facial and body movements. Since non-verbal communication is useful for species' survival, these capacities are probably due to an adaptive process (Darwin 1872). Visual attention is rapidly and automatically oriented to emotional bodies and faces (Vuilleumier and Schwartz 2001; Tamietto et al. 2005). A person observing another one performing his action can use visual information from his/her body language (i.e., body movement and facial expression) to understand his/her intention (for example, throwing a ball as far as possible) and emotional state (for example, the physical effort associated with the throw). Interestingly, these two cues are combined for understanding others' actions, suggesting that facial and body information are perceived as a whole (Meeren et al. 2005). When these two cues are incongruent, however, previous studies showed that the visual attention is more oriented to the face than to the body (Shields et al. 2012), and therefore suggested that the facial expression is more influential to understand others.

Body movement and facial expressions are two components of humans' body language. The potential use of body language is easily observed in sport situations (e.g., Urgesi et al. 2012). In baseball for example, it is well-known that some features of body language, for example leg position, arm extension or grip on the ball, can be used to anticipate the upcoming pitch (Gray 2002a, b). Such information belongs to the category of indirect information about the ball motion. As defined by Gray (2009, p115), direct information refers to "visual cues that could be used to accurately judge a particular quantity of ball motion, as distance or trajectory, while indirect information refers to cues that do not directly specify these quantities, but instead can be used to make educated guesses about what they will be." Importantly, the capacity to make use of this information seems an important feature of sport expertise, e.g., Kato and Fukida (2002) showed different visual search strategies between novice and expert batters before the pitcher makes his throw. In addition, if both novices and experts can use advance cues about the opponent posture, only experts seem able to detect deception from kinematics alone, as demonstrated by Sebanz and Shiffrar (2009). However, it seems that not all advanced cues are useful; for example, goalkeepers should not use information about the run-up during a penalty to avoid a possible deception. On the contrary, they should favor later information that emerges just before the initiation of the penalty taker's kicking action (Dicks et al. 2010). Advance cues are therefore an essential part of sport performance, in particular, when the timing constraint is high.

Indeed, the use of this indirect information would be inversely dependent on the amount of available visual information about the ball's trajectory (Gray 2009): The more visual information is gathered from the ball movement, the less the observer will need to use the body language seen before the throw. For example, when hitting a pitched ball, the time to make the spatial and temporal judgments is sometimes very short, and in such a case, the batter has no other choice than completing the visual information about ball's trajectory with the body language to make an educated guess about the ball's future path and arrival time. Hence, the use of body language should surface in particular when the viewing time is short. Our experiment aimed at testing this specific hypothesis.

The first experiment was designed to ensure that the body language and facial expression intensity (FEI) generated in our stimuli were perceived by the participants. Then, in a second experiment, we assessed the use of these cues in the prediction of a ball's spatial trajectory. Two visual cues were manipulated, namely the body language (body movement and FEI) and the occlusion time of ball trajectory (associated to the physical trajectory). Participants viewed videos of a pitcher throwing a ball with different amounts of body movement and FEI. After a given duration, the ball disappeared until the end of the trajectory, and the participants indicated their estimation of the ball's landing point. We expected that the body movement and FEI would influence significantly the landing point estimation for the longest occlusion times as the visual information about the ball's trajectory becomes more remote in time. When FEI and body movement information are incongruent (e.g., high FEI with a body movement associated to a short throw), we hypothesized, according to the literature, that FEI would outdo the information about body movement and therefore have a greatest influence on the estimation.

Experiment 1

Participants

Twenty participants (24.5 ± 2.67 years, mean ± SD) participated voluntarily after giving informed consent. All participants had normal or corrected-to-normal vision and were healthy and without any known oculomotor abnormalities. Participants were naïve with respect to the purpose of the experiment. This experiment was conducted in accordance with the Declaration of Helsinki.

Stimuli generation

Stimuli consisted of videos showing a 3D realistic character performing overhand throws. The movements were initially captured using a ten camera motion capture system (250e Optitrack, Natural Point, Corvalis, USA) at Université of Paris-Sud (France), where a subject volunteered to perform the throws. The participant was equipped with 54 markers on prominent bony landmarks (PlugInGait), and the full body motions were captured at a rate of 250 fps. The subject performed a series of throwing trials reaching different distances (11.5, 22.8, and 33.1 m). The process by which the whole trial was transformed into a realistic video involved three different steps: First, as the ball exited the capture volume, its whole trajectory was reconstructed mathematically offline. To this end, we froze its trajectory to the *X*–*Y* plane only, neglecting any variation in the *Z*-axis. Then, we computed the ball's *X* and *Y* velocities at the end of the capture and computed its trajectory by taking into account the ball's last captured position, gravity (on the *Y* axis only), and air resistance. Our reconstruction showed an accuracy of ±0.5 m compared to the real landing points. Finally, this offline computation of the final trajectory was then attached to the motion capture trial. As a second step, the whole movement was imported into the MotionBuilder® software in order to animate the virtual character's skeleton. Finally, in the third step, the skeleton character was associated with a realistic character using the 3ds max® software.

Different videos were created based on the 3D realistic character movements. We used two different camera positions in our virtual scene that were the same across the experimental conditions. The initial point of view (640 × 480 pixels) displayed the character during 500 ms at a rate of 60 fps from the beginning of arm movement (Fig. 1, first column) to the moment when the ball left his hand (Fig. 1, second column) and occupied roughly the lower left quarter of the screen. We created facial pain expression of various intensities based on Facial Action Coding System (Ekman and Friesen 1978) building on the fact that facial pain expression and facial expression of effort, whether cognitive or physical, share similarities (Ekman 1993; Frijda 2002; De Morree and Marcora 2010). Dynamical Facial Expression Intensities (FEI) were created with 3ds max® software and added on character's face during the initial viewpoint. The facial expression recruited the three action units (AU) of pain: AU4 caused brow lowering action, AU6&7 caused orbit tightening action, and AU9&10 caused levators contraction action. These AUs are known to be the main facial muscles conveying pain information (Prkachin 1992; Oliveira et al. 2007). FEI always began from neutral (0 %) at the first frame and either stayed neutral during all the video (hereafter called FEI0 %), or reached 50 % (FEI50 %) or 100 % of intensity (FEI100 %) at the last frame of initial viewpoint (after 500 ms) with constant increase.

Apparatus and experimental procedure

The videos were displayed on E-Prime® 2.10 installed on a HP computer (3.4 GHz Intel i5 CPU) which was used to run the experiment and record participants' answers. We report how we determined our sample size, all manipulations, and all measures in this study.

Two groups of participants took part in the experiment: One group was instructed to focus on the pitcher's face, whereas the second group had no attentional instruction. Participants sat on a chair facing the computer display located at a 0.55-m viewing distance. The eyes were aligned with the screen center. Each trial displayed a front view video at the bottom-left corner of the screen. The screen then turned blank with a black line of 45 × 0.5 cm (length × height). At the left end of this response scale was written (in French) "minimal effort," while at the right end of the black line was written "maximal effort." Participants had to judge the amount of effort produced by the pitcher when throwing the ball. To do so, participants were asked to click on the line at the point corresponding to judged pitch intensity, somewhere between the two extreme values.

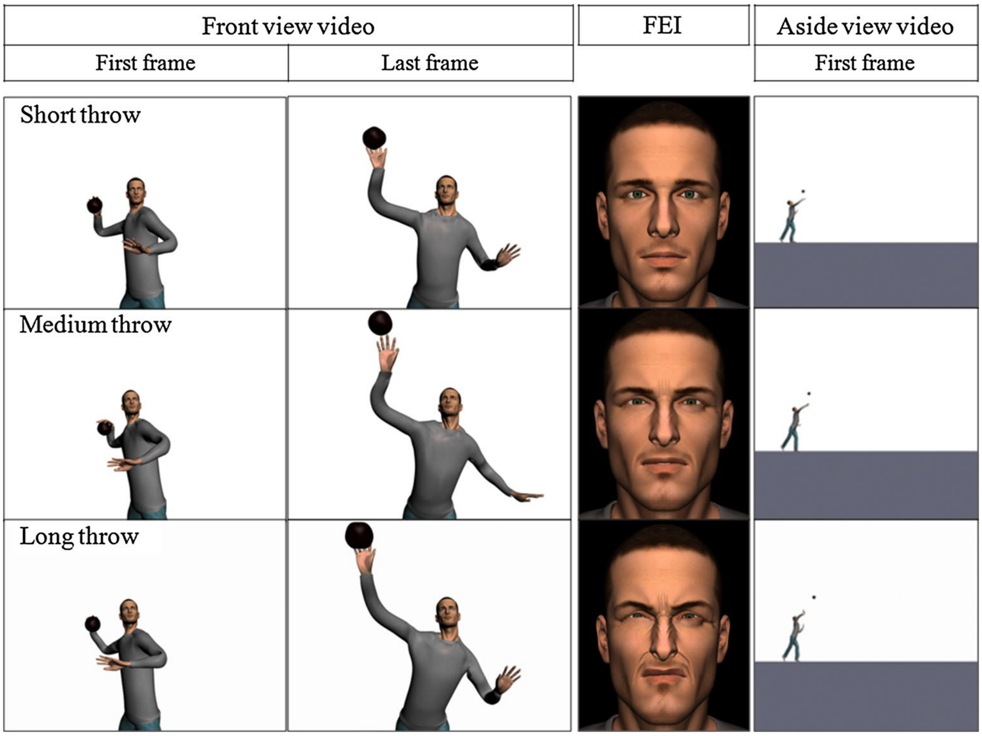

Fig. 1 Illustration of stimuli used in experiment 1 and 2. The first two columns illustrate the first and the last frames taken from three videos displaying a short, medium, and long throw with 0 % of FEI. The third column illustrates the three FEI: 0 % (neutral), 50 and 100 % of effort expression. The fourth column illustrates details of the first frame of the side view ("Experiment 2")

Then, the next video was displayed following a 1-s delay. Each of the nine body-language videos (i.e., 3 throws × 3 FEI, see Fig. 1) was presented four times in random order, for a total of 36 trials.

Pitch intensity, given by the pixel on the X axis, was converted in a scale from 0 to 100 and then analyzed with a mixed-model ANOVA with group (with instruction vs. without instruction) as between-subjects factor, and body movement (short, medium or long throw) and FEI (0, 50 and 100 %) as within-subjects factors. Huynh–Feldt correction (Huynh and Feldt 1976) of degrees of freedom was used when sphericity was not assumed, and the $\tilde{\varepsilon}$ value is reported. Partial η^2 is reported as a measure of association strength, and the 95 % confidence intervals (CI) of means are reported between brackets.

Results

The results showed no influence of the instruction on responses, $F(1, 18) = 0.02$, $p = 0.903$. Focusing attention or not on the pitcher's face did not modulate participants' judgment. Power analysis gave a small effect size[1] $f = 0.03$, confirming the weakness of the effect (Cohen 1988). A priori power analysis using G × Power 3 (Faul et al. 2007) indicated that given such an f value, in order to obtain a desired power of 0.8 (i.e., accepting a probability of type II error of 0.2), a total sample size of more than 8,200 participants would have been needed to reach significance. All these measures confirmed the lack of any significant effect of the instructions on the perception of effort.

On the other hand, body movement did influence the judgment, $F(2, 36) = 47.839$, $p < 0.001$, $\tilde{\varepsilon} = 0.73$, $\eta_p^2 = 0.73$. Tukey post hoc tests showed that intensity judgment increased significantly with body movement, with a mean judgment = 31.79, and 95 % [CI = (24.9; 38.68)] for short throws; [$M = 43.54$, (37.23; 49.91)] for medium throws, and finally [$M = 60.74$, (58.19; 68.44)] for long throws. The results also showed a significant influence of FEI, $F(2, 36) = 14.501$, $p < 0.001$, $\tilde{\varepsilon} = 0.70$, $\eta_p^2 = 0.45$. Tukey post hoc tests showed that FEI100 % led to significantly higher intensity judgments [$M = 52$, (44.53; 59.47)] than FEI0 % [$M = 39.66$, (33.64; 45.63)] and FEI50 % [$M = 44.41$, (38.1; 50.78)], with no difference between these two latter conditions. Finally, none of the interactions between the different factors reached significance.

Conclusion

Results of experiment 1 confirm that the participants do perceive and make use of all the available body-language

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[1] The f effect size indicator, strictly equivalent to ϕ', is worth $f = \sqrt{\frac{\eta^2}{1-\eta^2}}$ and corresponds to Cohen's d for multiple groups comparison. Its value is then compared to the usual Cohen's d thresholds divided by k, where k is the number of groups to compare (Howell 2006), to determine the importance of the effect.

signals to estimate the throwing effort of a pitcher, such as body movement (amplitude of the arm and trunk movements) and FEI. It is also worth noting that these cues are used, in particular the FEI, even if no instructions are given to the participants to focus their attention on the pitcher's face. This confirms previous work showing that FEI is a visual information rapidly perceived and understood by individuals (Vuilleumier and Schwartz 2001; Reed et al. 2003).

Experiment 2

Participants

Forty-eight participants (21.5 ± 2 years, mean ± SD) participated voluntarily after giving informed consent. None of them took part in experiment 1. All participants had normal or corrected-to-normal vision and were healthy and without any known oculomotor abnormalities. Participants were naïve with respect to the purpose of the experiment. This experiment was conducted in accordance with the Declaration of Helsinki.

Apparatus and experimental procedure

The experiment was run on the same computer as experiment 1. Stimuli presentation began in the same way: In a trial, one of the nine body-language videos (i.e., 3 throws × 3 FEI front views, see Fig. 1) was displayed at the bottom-left corner of the screen at its full resolution (640 × 480 pixels). At the end of the video, and with no delay, a second video was presented, again at its full resolution (1,920 × 1,600 pixels). This second video displayed the side view of a character at a distance from the frame following that of the previous point (Fig. 1, fourth column) to the landing frame. Depending on the throwing distance, the duration of this second video was 1,300, 1,833, or 2,066 ms for short, medium, and long throws, respectively. This point of view was chosen in order to make the ball visible even in the long throw condition and to give the participants the opportunity to estimate the landing point beyond the correct answer (e.g., the landing point of the long throw was more than 492 pixels, corresponding to approximately 11 cm, before the edge of the screen). In order to prevent large saccadic eye movements during the viewpoint change (between the launcher front and aside views), we displayed frames of the first point of view at the bottom-left corner of the screen positioned close to the screen position of the character viewed at a distance from the side. The distance travelled by the ball corresponded to the distance indicated by the body movement (e.g., short travelled distance for a body movement indicating a short throw, etc.). This gave rise to nine possible combinations of FEI and body movement condition. Each of these combinations was presented five times in a random order, for a total of 45 trials.

In addition, viewing time of ball trajectory was varied across groups of participants to test our hypothesis that body movement and FEI modulation of response would vary with the amount of ball trajectory available. Depending on group, the ball was presented for a specific amount of time, and then, it disappeared until the end of the trajectory. Participants were then requested to click on the ground at the ball's estimated landing point. Groups were defined depending on the amount of occlusion time of ball's trajectory. For the 25 % occlusion group, the ball was visible for 75 % of its trajectory and then disappeared for the remaining 25 %. The 50 % occlusion group viewed 50 % of the ball's trajectory, whereas the 75 % occlusion group viewed 25 % of the ball trajectory. Finally, in the 100 % occlusion group, the ball's trajectory was not visible at all, and the ball disappeared as soon as it left the pitcher's hand. Each group included 12 participants.

Response error was computed as the difference between the estimated and genuine landing points (positive error indicated an overestimation of the landing point and, conversely, a negative error was an underestimation). Genuine landing points were at pixels 599, 968, and 1,428 for the short, medium, and long throws, respectively, and maximal response was at pixel 1,920. We decided to analyze the error in pixel, as this was the measure produced by the participants. The error was thus analyzed with a mixed-model ANOVA with occlusion time (25, 50, 75, and 100 %) as between-subjects factor, and body movement (short, medium, or long throw) and FEI (0, 50 and 100 %) as within-subjects factors. Huynh–Feldt correction (Huynh and Feldt 1976) of degrees of freedom was used when sphericity was not assumed, and the $\tilde{\varepsilon}$ value is reported. Partial η^2 is reported as a measure of association strength, and the 95 % CIs of means are reported between brackets. However, to better understand the contribution of the different factors and their consequences in real-life situations, the results have also been converted in real-world units (e.g., errors as the distance in meter between the estimated and genuine landing points) and reported hereafter to the readers.

Results

The ANOVA showed a significant influence of occlusion time on error, $F(3, 44) = 8.83$, $p < 0.001$, $\eta_p^2 = 0.38$. Tukey post hoc tests showed that the 100 % occlusion group made higher errors than all other groups, whereas the other groups did not differ between each other. The error was also significantly affected by the pitcher body movement,

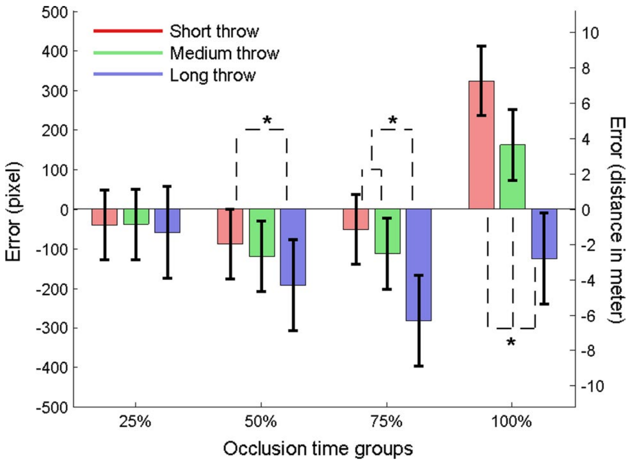

Fig. 2 Error in pixel (*left Y axis*) or in real-world distance (in meter, *right Y axis*) in the estimated landing point as a function of participants' group of occlusion time and body movement. *Asterisk* indicate significant differences between the body movement conditions for a given occlusion time group. *Error bars* show the 95 % CI obtained from the ANOVA. *Error bars* not covering 0 indicate that the mean value is significantly different from zero ($p < 0.05$)

$F(2, 88) = 103.17$, $p < 0.001$, $\tilde{\varepsilon} = 0.64$, $\eta_p^2 = 0.70$. It became significantly more and more negative as the body movement indicated a longer throw. In addition, there was a significant occlusion time × body movement interaction, $F(6, 88) = 21.99$, $p < 0.001$, $\tilde{\varepsilon} = 0.64$, $\eta_p^2 = 0.60$ illustrated in Fig. 2. Post hoc tests showed that the influence of body movement potentiated with increasing amount of occlusion time. Indeed, no difference was found in the error due to the body movement for the 25 % occlusion group. For the 50 % occlusion group, the error was different only between the body movement indicating short versus long throws. For the 75 % occlusion group, the error due to the body movement differed between long throws and both a short and medium throws, with no difference among these two latter conditions. Finally, for the 100 % occlusion group, all errors significantly differed with body movement condition. In this latter group, mean participants' errors are positive when body movement indicated short and medium throws. A positive error corresponds to an overestimation of the landing point, possibly due to people's incorrect belief of acceleration continuation. Indeed, it has been shown that people consider that a ball can continue to accelerate after been thrown, especially when the thrower's arm presents accelerating properties (Hecht and Bertamini 2000). Finally, the results failed to show an influence of FEI, $F(2, 88) = 0.66$, $p = 0.52$, and this factor did not interact significantly with any other, as well.

To investigate further on the lack of significant influence of FEI, we decided to compare the error made at the first repetition and the last repetition. We conducted a mixed-model ANOVA with occlusion time (25, 50, 75, and 100 %) as between-subjects factor, and body movement (short, medium, or long throw), FEI (0, 50, and 100 %) and repetition (first and last repetitions) as within-subjects factors. Huynh–Feldt correction (Huynh and Feldt 1976) of degrees of freedom was used when sphericity was not assumed, and the $\tilde{\varepsilon}$ value is reported. Partial η^2 is reported as a measure of association strength. Only the significant main effects or interaction effects of the repetition factor are reported.

Repetition had a significant influence on error, $F(1, 44) = 75.374$, $p < 0.001$, $\tilde{\varepsilon} = 1$, $\eta_p^2 = 0.63$. Mean error was positive for the first repetition [M (in meters) = 1.20, (0.20; 2.19)], but turned to be negative at the last repetition [$M = -1.15$, (−2.01; −0.29)]. The ANOVA also showed significant interactions of Repetition × Body movement, $F(2, 88) = 91.01$, $p < 0.001$, $\tilde{\varepsilon} = 0.87$, $\eta_p^2 = 0.67$ and Repetition × FEI, $F(2, 88) = 145.44$, $p < 0.001$, $\tilde{\varepsilon} = 0.99$, $\eta_p^2 = 0.77$, but these two effects were downgraded by a second interaction effect of Repetition × Body movement × FEI, $F(4, 176) = 83.565$, $p < 0.001$, $\tilde{\varepsilon} = 0.83$, $\eta_p^2 = 0.66$. Tukey post hoc tests showed that at the first repetition, FEI had no influence for the short and medium throw on the error. However, for the long throw first repetition, FEI 100 % led to a significantly more negative error than FEI 0 and 50 %, with no difference between these two latter conditions. Such an effect of FEI was not present anymore at the final repetition, as FEI did not influence the error for any of throws (Fig. 3).

General conclusion

Body language carries relevant information to judge the amount of effort produced by a pitcher throwing a ball. Whether instructed or not to pay attention to facial signal, participants combined the variation in the intensity of the latter with the amount of body movement to estimate the throwing effort (see "Experiment 1"). However, when extrapolating the landing point of a ball, this advance information is not entirely exploited. For its part, body movement is taken into consideration to estimate the landing point of a thrown ball. In addition to visual information concerning the ball's trajectory, observers also make use of information incoming from the pitcher's movement. Body movement is indeed an important cue in such a task, since it builds the forces and transmits them to the ball, giving rise to its flight. However, things are subtler than this when estimating ball's landing point, as evidenced by the interaction between body movement and the occlusion time. Body movement information gets more perceptual weight when the ball's trajectory becomes less visible. This confirms previous studies that have shown that cognitive factors, such as knowledge of gravity, became more intrusive in the perceptual judgments and are given more weight as

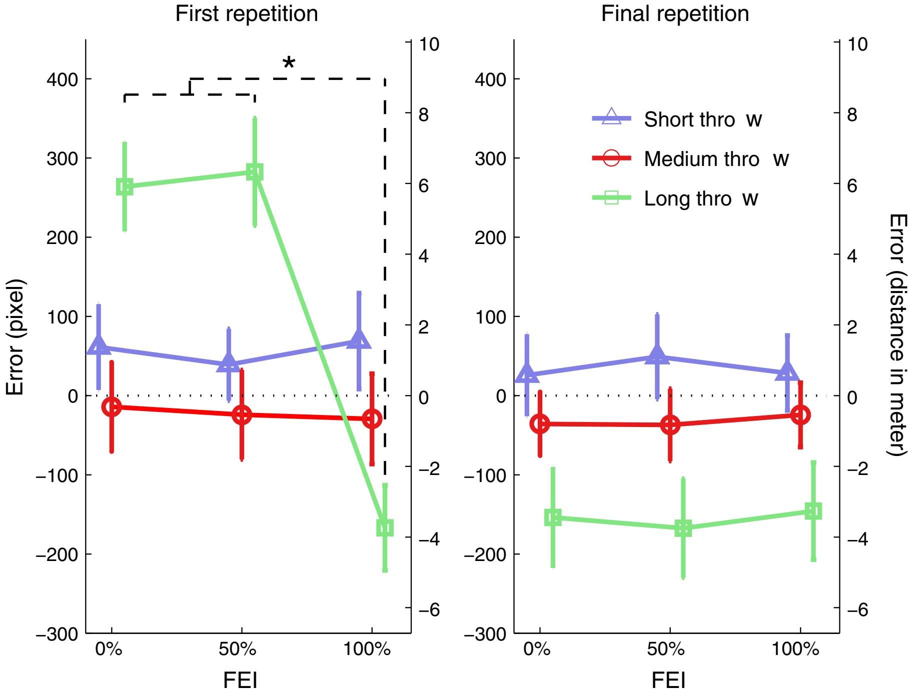

Fig. 3 Error in pixel (*left Y axis*) or in real-world distance (in meter, *right Y axis*) in the estimated landing point as a function of trial repetition, body movement, and FEI. *Asterisk* indicate significant differences between the FEI conditions for a given body movement and repetition. *Error bars* show the 95 % CI obtained from the ANOVA

the visual information about ball motion becomes progressively more remote (Baurès and Hecht 2011; Bosco et al. 2012).

However, FEI does not appear to play a major role for estimating a ball's landing point ("Experiment 2"), although experiment 1 showed that FEI could be perceived and used by the observers when judging the thrower's effort. In experiment 2, FEI mainly influenced the initial experimental trials suggesting that our participants interpreted the two lowest facial expressions (i.e., FEI 0 and 50 %) as a mimic made by the thrower suggestive of an ease to reach the farthest landing point rather than the involvement of less energy in the throw. Hence, FEI is not used as an indication of the landing point, but rather as an estimation made by the observer about the thrower's capacities. However, such an effect disappears with trial repetition. Two questions arise from these observations.

Firstly, it is worth wondering why FEI is used in the effort judgments, but not in estimating the landing point. Our results suggest that observers would consider FEI to be less predictive of ball motion than body movement. While body movement gives the ball its motion, this is not true for FEI. FEI would be related to the amount of effort, but the connection between FEI and ball's landing point would be indirect and suspicious. For example in baseball, it is important for the hitter to avoid the pitcher's feint, for example when the pitcher displays a strong facial contraction while throwing a slow pitch to deceive the hitter. Similarly, it has been shown that people learn to suppress and control facial display of pain either to hide vulnerability in the presence of antagonists (Peeters and Vlaeyen 2011) or to avoid embarrassing others (Williams 2002). Facial expression of pain can be different depending on the presence or absence of an observer (Williams 2002). Hence, in the current experiment, while the FEI might be useful to perform the task, its truthfulness may appear too doubtful to make use of it, and consequently, observers do not take it into account to perform their estimation. In addition, given the short presentation time that was used in experiment 2, observers may have had choose which information to rely on since they were unable to attend to all visual cues. Many studies highlighted the dominance of emotional face information to attract an observer's visual attention (Vuilleumier and Schwartz 2001). Moreover, when face and body information is incongruent, visual attention seems to be oriented to the face rather than the body (Shields et al. 2012). Moreover, it appears that visual information displayed by others can be perceived and processed automatically, especially emotional information which could be first processed by subcortical structures, i.e., amygdala, hypothalamus, and brainstem, before to be processed by cortical structure, i.e., sensory cortex and prefrontal cortex (Zhu and Thagard 2002). According to these results, we hypothesized that FEI would outclass information about body movement. Our results contradict this assumption, showing that participants attributed a greater weight to body movement than to FEI. Markedly, our participants preferred to use the most reliable and visible cue, which in our case was body movement. In other words, the information about body movement may outdo the information about FEI, leading the observer to use only the most salient and reliable among the two cues. It is possible that participants assigned different weights to the different visual information in order to estimate the landing point. Since body movement information (displayed in the initial viewpoint video) was very prominent and congruent with the ball's trajectory, they assigned stronger weight to this information and a lower weight to FEI. According to the Information Integration Theory, the weighting of different sources of information can be influenced by the task and the context (Anderson 1996) and by the observer's level of familiarity and expertise (Prigent et al. 2014). The level of ambiguity of given information can influence the relative weight assigned to two incongruent sources of information (Van den Stock and de Gelder 2007). Alternatively, we cannot rule out that the role of FEI may have been minimized by our choice of task design. In our experiment, body movement available from the initial viewpoint was always associated with corresponding parabolic trajectory of the ball viewed from the side, whereas FEI varied randomly across trials within each group. Therefore, FEI was not consistent with ball's trajectory and was therefore not predictive of ball's landing point. Therefore, the lack of reliability could result from our design of the task, rather than from the potential prevalence of body movement over FEI to judge the landing point of a thrown ball. Such an assumption should be tested in another task by varying FEI and ball trajectory in a fully factorial design body movement. We theorize that if body movement information had been more ambiguous about ball's landing point, participants would attribute a more important weight to FEI to make their estimation. Moreover, because observer expertise can improve the prediction of others' actions (Tomeo et al. 2012), it would be interesting to study the effect of an observer's expertise in throwing a ball on the estimation of landing point, as well as its interaction with levels of ambiguity in actions.

Secondly, why would FEI initially be used as an indication of thrower's capacity, but not after trial repetition? This effect may reflect observers' adjustment in gathering the information and using it to perform the task. FEI was shown less reliable (either because of the prevalence of body movement over FEI or due to our design); however, such an unreliability may require many trials to be perceived. Hence, during the first trials, because FEI and body movement were sometime incongruent, visual attention of participants was supposedly oriented toward the face. It could explain why they took into account FEI—although with a limited influence, however (see Fig. 3), for the above explained reasons—in their estimation during the first trials. However, with repetition, observers might have learned that FEI is not a reliable cue indicating the thrower's capacities and possibly did not consider it anymore in the remaining repetitions.

Which neural substrates may subtend the change in weighting of the two sources of visual information from body language (i.e., facial expression and body movement) across trial repetition? Amygdala is a subcortical structure which allows rapid processing of emotional content (Zhu and Thagard 2002), including visual information from facial expressions displayed by others. It is part of the mirror neuron system (Bastiaansen et al. 2009), a neural network involved in acting but also when observing someone carrying out similar action (Iacobini and Dapretto 2006). Amygdala is involved in both overt and covert imitation of emotional facial expressions (Carr et al. 2003) and in deciphering the emotional states of our conspecifics (Iacobini 2009). Building on recent models from social neuroscience, we may theorize that our participants initially perceived the virtual character with two main parallel neural streams: One fast and automatic processing subtended by the mirror neuron system (including amygdala), and a second more reflexive and controlled processing (Keysers and Gazzola 2007; Decety and Lamm 2006). During the first trials, facial pain expression may have been automatically perceived via resonance of common mirror structures activated during one's own experience of pain and perception of others' pain (Botvinick et al. 2005). However, after repetition, the more reflexive and controlled process may have taken over and lead participants to attribute a greater weight to body movement than to facial expression.

In summary, our results show that advance information from the thrower may be used under specific conditions to anticipate a ball's spatial trajectory. When the ball is visible only briefly, information about the pitcher's body movement is used to supplement the missing information about ball motion. In this sense, observers buy some time by making an educated guess (Gray 2009) about the ball's spatial trajectory based on the pitcher's body language. However, only reliable visual cues are used in this situation; visual information about body movement outweighs information about FEI. It remains for future research to assess how observers perform if body movement would have contradicted the apparent ball's motion. In the present experiment, body movement was predictive of ball's travelled distance since both were always congruent (i.e., a body movement indicating a short throw followed by a short throw). If the two videos would have suggested two different landing points, our results would predict a strong influence of the occlusion time on the performance, with participants basing their answer on the visible ball motion for the shorter occlusion time and allocating more weight to body movement, while the occlusion time increases. This, however, remains to be tested.

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Conflict of interest The authors declare that they have no conflict of interest.

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