

# Time flies when we view a sport action

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**Abstract** Humans' time evaluation within the range of hundreds of milliseconds is often distorted, and time is judged as much longer than actually is. This consistent overestimation has been interpreted as an indicator of the threshold level for the sensitivity of the perceptuomotor system. The purpose of this study was to investigate how the perception of time, both in sub- and supra-second timescales, changes for elite athletes that are considered as individuals with highly developed motor perceptual capabilities and with great sense of time particularly for the extremely short timescales. For this purpose, we asked elite pole-vaulters to reproduce the exposure times of a familiar image showing a pole-vault jump and non-familiar images as a fencing lunge and scrambled pixels and compared their estimates with controls. While the time distortion in the supra-second range was similar for athletes and controls independently from the image presented, in the sub-second range of time, athletes were more accurate and less variable than controls, while for all the participants, the images were perceived differently. Time was perceived as shorter when viewing the pole-vault jump image followed by the fencing lunge and last the scrambled pixels, providing the evidence that action observation distorts individuals' time perception by compressing the perceived passage of time. Remarkably though pole-vaulters' higher precision and lower variability than controls indicate their ability to

compensate for this distortion due to a well-refined internal clock developed through sport training.

**Keywords** Time perception · Time evaluation · Time reproduction · Implied action · Action observation · Elite athlete

## Introduction

Thanks to the extended and sustained training, elite athletes acquire an excellent ability in perceiving and performing fast actions in the space–time domain (e.g., Bootsma and Van Wieringen 1990; Aglioti et al. 2008). It is particularly relevant their ability to estimate time when dealing with the extremely short scales in terms of hundreds of milliseconds. Humans' time perception within this range is often distorted (review see Eagleman 2008), and time is judged as much longer than actually it is (e.g., Wearden 2003; Wearden and Lejeune 2008). This consistent overestimation has been interpreted as an indicator of the threshold level for the sensitivity of the perceptuomotor system, while within this range the cognitive engagement, such as attention and working memory capacity, appears to be more limited (Lewis and Miall 2003; Rammsayer 1999).

Recently, it has been shown that time estimation is influenced by action observation even when the action observed is merely implied as in a static image (Chen et al. 2013; Moscatelli et al. 2011; Nather and Bueno 2011; Nather et al. 2011). The exposure time of photographs showing skaters in action is estimated with a higher precision compared to the photographs showing the same skaters but in a standing posture (Moscatelli et al. 2011). Interestingly, time seems to be lengthened corresponding to the movement magnitude implied (Nather and Bueno 2011; Nather

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et al. 2011; Yamamoto and Miura 2012). For instance, while individuals estimate the exposure time of pictures showing different ballet postures, the greater the movement magnitude implied by the posture presented the longer the estimated time (Nather and Bueno 2011; Nather et al. 2011). The authors interpreted this effect as a consequence of an internal action simulation in that the more amount of movement implied the longer the time for simulating the entire action (Nather and Bueno 2011; Nather et al. 2011). Notably in these previous studies, even though the stimuli delivered ranged from sub- to supra-second, the analysis considered the general mean of the data. However, by inspecting the data just for the briefer timescale (i.e., sub-second time), in both studies the tendency seems to be opposite and individuals evaluated as shorter the exposure time of the images representing greater movement magnitude (Moscatelli et al. 2011; Nather et al. 2011). This incongruence might be due to the little amount of attention that is allowed in sub-second timescale (for review see Grondin 2010). Therefore, the initial aim of this study was to test time estimate in sub-second range, while individuals were represented with picture showing different sport actions. Time estimates in supra-second range of time were also observed for comparison.

An additional relevant feature that may affect time evaluation is the level of familiarity with the movement observed. Recently, we found that professional pianists show better time reproduction ability than non-pianists with less estimation error and lower variability particularly for the images showing piano-playing actions (Chen et al. 2013). It has been shown that through mental practice (MT), humans are able to simulate and time the action that they learn (Bakker et al. 2007; Felz and Landers 2007; Wehner et al. 1984) and in particular for sport athletes (Guillot and Collet 2005). Therefore, here a group of elite pole-vaulters was asked to perform a time reproduction task, while they were presented with an image of a familiar action (i.e., pole-vault jump), non-familiar action (a fencing lunge), and an image made of scrambled pixels as control. The pole-vaulters' performance was then compared with individuals without any pole-vault experience. Meanwhile, we examined participants' capacity to recall features presented in the images by administering a questionnaire.

Following previous studies' indications (Moscatelli et al. 2011; Nather et al. 2011), we anticipated that the observation of a highly dynamic action would shorten participants' time estimation, particularly in sub-second range of time. Furthermore, due to the familiarity with the action presented, we expected that elite pole-vaulters would present less reproduction error and lower variability than the controls particularly for the image representing the pole-vault jump (Chen et al. 2013). This hypothesis would be

supported by their better recall of the features of the pole-vault jump image.

## Methods

### Participants

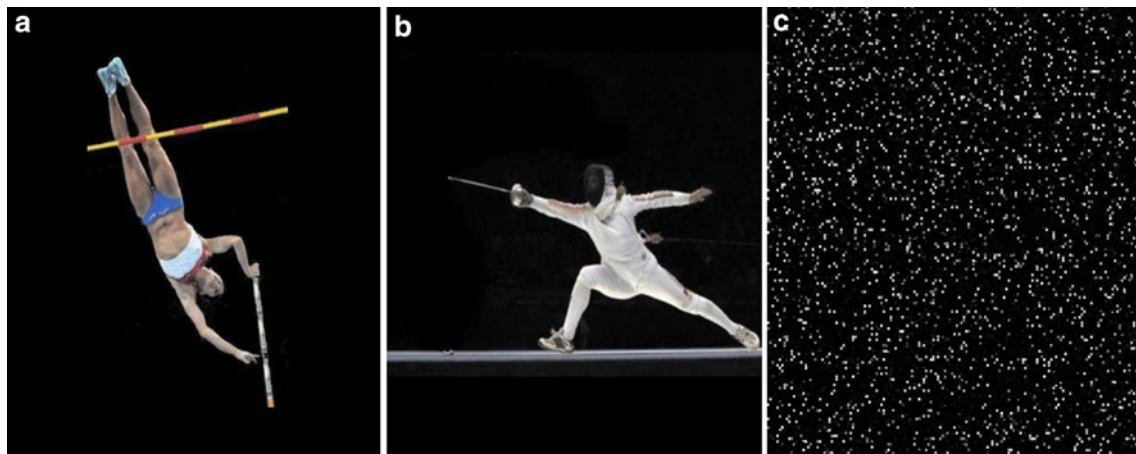
We recruited twelve elite pole-vaulters (nine males and three females; mean age of  $26.8 \pm 4.0$  years) and twenty-three non-athletes as controls (ten males and thirteen females; mean age of  $28.0 \pm 4.7$  years). Elite pole-vaulters have a mean of  $11.2 (\pm 3.3)$  years of training experience and are active in participating competition at least in national level. The control group had no experience in pole vault and fencing or any other sport at a competitive level. All participants had normal or corrected-to-normal vision and were naïve about the purpose of this study. All of them gave written informed consent to the study in accordance with the procedure approved by the ethics committee of Department of Neurological and Movement Sciences, University of Verona, Italy.

### Task

We used a version of the time reproduction task previously used by other authors (cf. Brown 1995). Participants were presented with a visual stimulus for a certain temporal interval, and they had to reproduce this stimulus temporal interval as precisely as possible by pressing the spacebar on the computer keyboard with their index finger of the dominant hand. No feedback was given.

### Materials and procedure

The experiment was conducted in a small cubicle, insulated from external lights and noise. Participants were seated opposite a 19-in computer monitor ( $1,280 \times 1,024$ , 75 Hz) with a keyboard placed at a distance of 60 cm in front of them. The experimental program was written using MATLAB 7.1 and Cogent 2000, which assured millisecond accuracy for stimulus and reproduced temporal interval. Stimuli were the static image of a pole-vaulter rotating her body over the bar (hereafter refer to 'pole-vault jump'), a fencer maintaining an attacking lunge posture (hereafter refer to 'fencing lunge'), and an image of scrambled pixels ('scrambled pixels'; see Fig. 1). The image ( $20 \text{ cm} \times 16 \text{ cm}$ ) was displayed on a black background and located in the center of the screen for 16 different temporal intervals (from 300 to 1,000 ms in 100 ms steps for sub-second range of time and from 1,100 to 1,800 ms in 100 ms steps for supra-second range of time). A fixation cross was displayed for 2 s before the exposure of the



**Fig. 1** Experimental stimuli. **a** The image of a pole-vaulter rotating her body over the bar (pole-vault jump). **b** The image of a fencer maintaining a lunge posture (fencing lunge). **c** The image of scrambled pixels (scrambled pixels)

stimulus. The task was explained to the participants by on-screen instruction, which were clarified when necessary by the experimenter. A few practice trials were given to ensure that the task was fully understood. The 8 different sample temporal intervals in the sub-second and the 8 ones in the supra-second range of time were tested separately, both in a randomized order, and each of the temporal intervals was tested for 8 repetitions for a total of 384 trials (3 pictures  $\times$  16 temporal intervals  $\times$  8 repetitions). After all the testing trials, participants were asked to recall the features presented. For pole-vault image, the questions were the gender of the pole-vaulter, the color of the pole-vaulter's pants and shoes. For fencing picture, the questions were the gender and handedness of the fencer, and the color of the fencer's mask. As for scrambled pixels, we asked for the shape of the picture frame. The experimental procedure took approximately 1 h.

### Data analysis

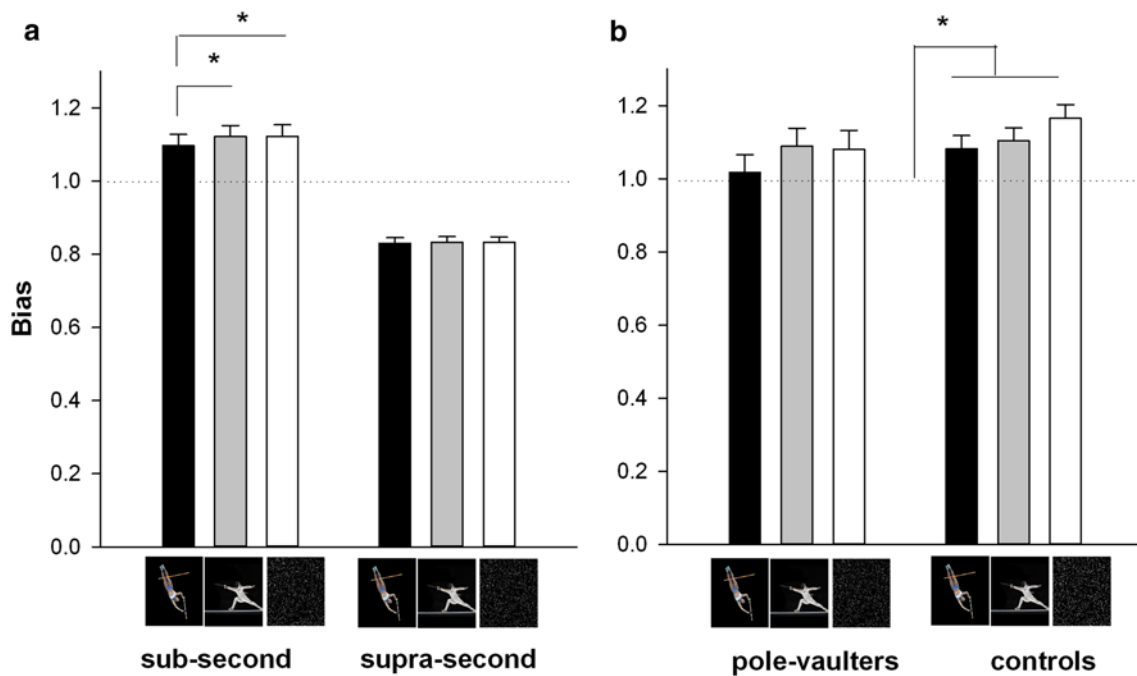
Three characteristic variables regarding time estimates were calculated: (1) the ratio between reproduced and stimulus temporal time, in order to observe participants' reproduction bias (hereafter refer to 'bias'). It indicates whether the sample temporal interval was overestimated (a value  $<1$ ) or underestimated (a value  $>1$ ); (2) the ratio between the absolute errors of the reproduced and the respective sample time (hereafter refer to 'AE ratio') to study participants' reproduction error; (3) the coefficient of variation (CV) of the reproduced time as the percentage of standard deviation to the mean of the reproduced time, to study participants' reproduction variability. For each variable, we calculated the mean of the data points derived from the sample temporal intervals and compared in three-way repeated measures ANOVA with image (pole-vault jump,

fencing lunge, and scrambled pixels) and range of time (sub- and supra-second range) as within-subject factors and group (pole-vaulters and controls) as between-subject factor. Based on our hypothesis that different processes are involved in the reproduction of short and long intervals, the intervals between 800 and 1,300 ms were considered as a hypothetical 'transition zone' and not included in the analysis in order to separate the two processes more clearly. For the questionnaire part, we compared the numbers of correct answers for the three images per group. We performed three separate nonparametric two independent samples tests (Mann–Whitney  $U$  test) for three images to compare the difference between two groups. IBM SPSS statistics 20 was used for statistical analysis. The significance level for all tests was set at  $p < .05$ . A Bonferroni adjustment was used when making multiple comparisons.

### Results

#### Reproduction bias (Bias)

As illustrated in Fig. 2a, we found a significant main effect of range,  $F(1, 33) = 86.700$ ,  $p < .001$ , with sub-second time intervals were overestimated (bias = 1.090) while supra-second time underestimated (bias = .827). Main effect of image was also found significant, showing that pole-vault jump image was underestimated with a greater bias size than fencing jump image and scrambled pixels (mean value of .934, .963, and .978, respectively),  $F(2, 66) = 8.350$ ,  $p < .001$ . Moreover, we found a significant image-by-range interaction,  $F(2, 66) = 6.369$ ,  $p < .005$ . Post hoc analyses indicated that the image difference (as reported in the result of main effect) was only significant for sub-second range of time (mean value of 1.050, 1.097, and 1.122 for pole-vault jump,



**Fig. 2** **a** All participants' average reproduction bias (=reproduced time/sample time) for the three different images in sub- and supra-second range of time. **b** Average reproduction bias of pole-vaulters

and controls for the three different images in sub-second range of time. Dash line indicates the situation in which images were not over- nor underestimated. Error bars indicate standard errors.  $*p < .05$

fencing lunge, and scrambled pixels image, respectively). For supra-second range of time, three images were estimated with similar bias. The group effect,  $F(1, 33) = .803$ ,  $p = .377$ , and the other two- and three-way interactions were not found significant. In order to furthermore investigate whether the aforementioned over- and underestimations were significantly different from 1, we performed one sample t test for the data of each group per condition. As shown in Fig. 2b, we found that pole-vaulters did not show significant bias from 1 for estimating sub-second time intervals, no matter for which images ( $p = .720, .102, .142$  for pole-vault jump, fencing lunge, and scrambled pixels image, respectively), whereas they showed significant underestimations for supra-second time estimates for all images ( $p < .000$ ). Instead, controls showed significant overestimations for sub-second time estimates and underestimations for supra-second time estimates, for all images ( $p < .000$ ).

#### Reproduction error (AE ratio)

The ANOVA (3 images  $\times$  2 groups  $\times$  2 ranges of time) detected a significant main effect group,  $F(1, 33) = 4.629$ ,  $p < .050$ , with pole-vaulters making less error than controls (mean value of .223 and .254). The main effect of range was also significant,  $F(1, 33) = 37.182$ ,  $p < .001$ , with sub-second times estimated with higher error than supra-second times (respective mean value of .283 and .193).

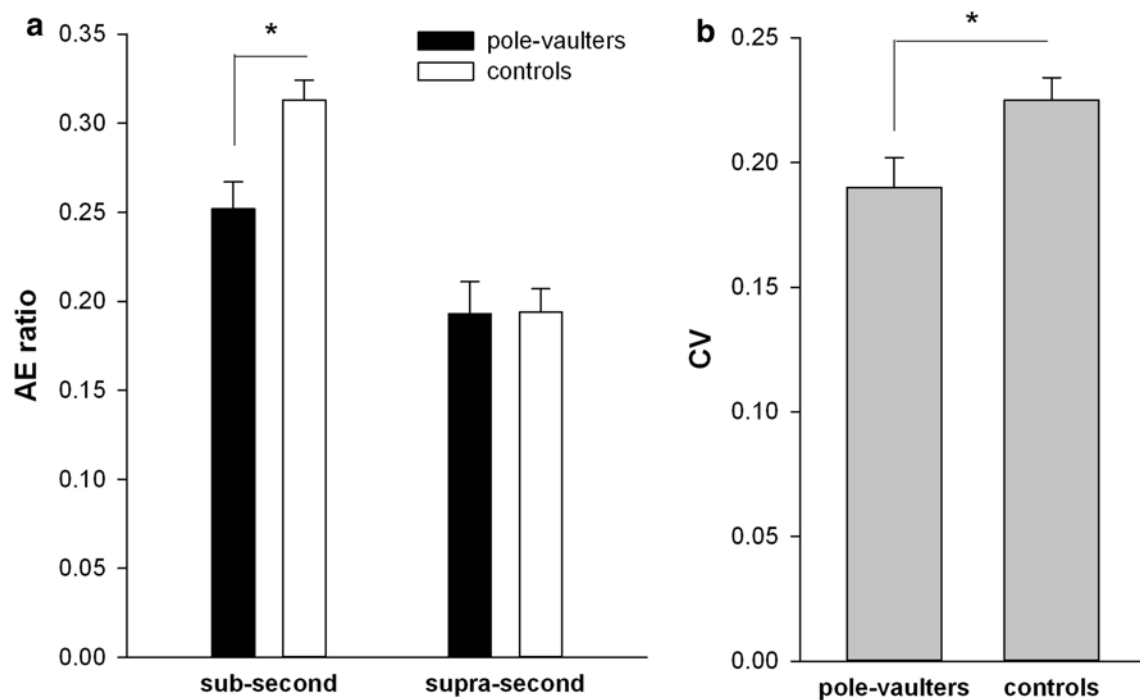
There was marginal significant range-by-group interaction,  $F(1, 33) = 4.112$ ,  $p = .051$ . Post hoc comparisons demonstrated that group difference was significant in the sub-second range of time ( $p = .003$ ) but not in the supra-second range of time ( $p = .952$ ). Range-by-image interaction was also significant, again with range effect for every image ( $p < .000$ ). The main effect of picture,  $F(2, 66) = .503$ ,  $p = .607$ , image-by-group,  $F(2, 66) = 1.428$ ,  $p = .247$ , 3-way interactions,  $F(2, 66) = 2.898$ ,  $p = .062$ , were not found significant (see Fig. 3a).

#### Reproduction variability (CV)

Shown in Fig. 3b, a significant main effect of group was found,  $F(1, 33) = 5.153$ ,  $p < .050$ , showing that pole-vaulters reproduced the times with lower variability than the controls (respective mean value of .190 and .225). There was also a significant main effect of range, with sub-second times estimated with higher variability than supra-second times,  $F(1, 33) = 157.930$ ,  $p < .000$  (respective mean value of .256 and .159). The main effect of image,  $F(2, 66) = 2.093$ ,  $p = .131$ , and all of the interactions were not significant.

#### Correctness of answering the questionnaire

Pole-vaulters demonstrated significant greater number of correct answers for pole-vault jump image than controls,



**Fig. 3** **a** The average reproduction error (AE ratio = absolute error/sample time) of pole-vaulters and controls in sub- and supra-second ranges. **b** The average reproduction variability (CV = SD/mean of

reproduced times) for pole-vaulters and controls. Error bars indicate standard errors. \* $p < .05$

mean rank value 26.63 and 13.50, respectively, for pole-vaulters and controls,  $U(1) = 34.500$ ,  $Z = -3.758$ ,  $p < .001$ . No such difference was found for fencing lunge image, mean rank value 17.00 and 18.52,  $U(1) = 126.000$ ,  $Z = -.457$ ,  $p = .694$ , and for scrambled pixels, mean rank value 20.58 and 16.65,  $U(1) = 107.000$ ,  $Z = -1.339$ ,  $p = .294$  (see Fig. 4).

## Discussion

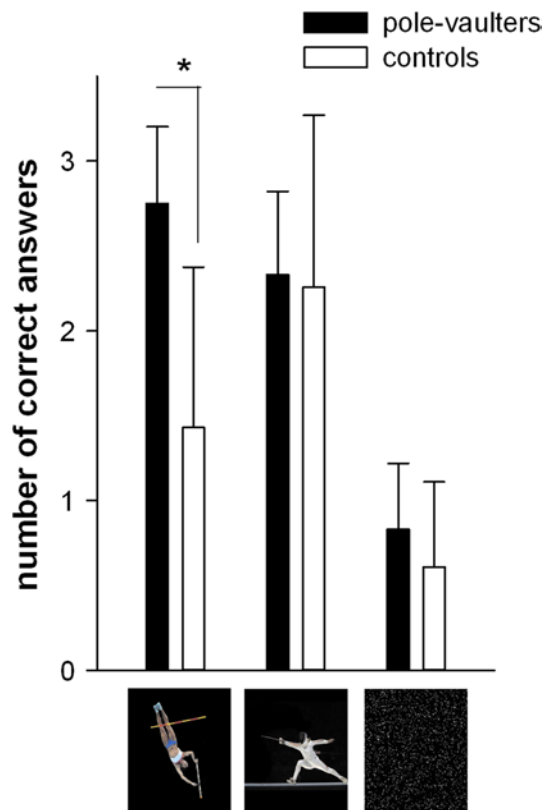
The purpose of this study was to investigate the impact that observing an action (when it is implied in a static photograph) has in perceiving the passage of time, by focusing the attention on the sub- and supra-second timescales. We were interested in understanding whether the level of familiarity of the movement observed would influence time perception. Thus, we asked elite pole-vaulters to reproduce the exposure times of images showing a familiar action (a pole-vault jump), a non-familiar action (a fencing lunge), and a scrambled pixels and compared their estimates with controls.

As a general result, we found that all the participants, no matter pole-vaulters or controls, reproduced the shortest time for the image representing the highly dynamic action (i.e., pole-vault jump), followed by the image representing the less dynamic action (i.e., fencing lunge), and finally the

longest time for the scrambled pixels image. Importantly, we found that this tendency was significant when the time to be reproduced was shorter than a second. This result seems to be in opposition with previous findings showing that perceived time is lengthened as a function of the amount of movement represented (Moscatelli et al. 2011; Nather et al. 2011). However, the aforementioned authors did not analyze their data considering the two ranges of time separately. In fact, two different tendencies for two ranges of time can be observed (even though no related statistics was reported): In the sub-second range of time, participants estimated a shorter time for images with greater implied movement as found in the current study, whereas in the supra-second time, there was the opposite tendency. Indeed, it has been shown that two distinct mechanisms for temporal processing are identified for time above and below a second, supported by pharmacological manipulation, psychophysics, and neural network modeling (review see Buhusi and Meck 2005; Lewis and Miall 2003). Along with the robust findings, sub-second times are usually overestimated while supra-second times underestimated (review see Wearden and Lejeune 2008) as revealed in this study.

Above all, why in principle an image implying a dynamic action is perceived shorter than an image without implied action even though their exposure times are actually the same? It could be possible that attentional allocation plays a fundamental role in distorting the perception of





**Fig. 4** The average number of correct answers for pole-vaulters and controls when they were asked to recall the features of the three different images. Note that we compared the group difference by three nonparametric 2-samples tests for the three images, respectively.  $*p < .05$

time (Grondin 2010). In our case, while viewing a highly dynamic action image, the attentional resources were limited by both the brief time available and by the overwhelmed amount of information to process. Typically, it is assumed that attention is a limited capacity system, thus the less the attention is available the shorter the time passage is perceived (Brown and West 1990; Brown et al. 1992; Coull et al. 2004).

As shown in the literature, individuals without any sport expertise overestimated the brief time intervals with poor accuracy and large variability (Wearden and Lejeune 2008; Chen et al. 2013). Here instead pole-vaulters did not present specific bias for overestimating the time, particularly for time in sub-second range, being highly precise and stable. That is, athletes were able to keep their reproduced times closed to the time target without showing a particular direction of estimation bias with higher accuracy than the non-athletes. Moreover, they could minimize the dispersion of their reproduced times around the target and thus showed the lower reproduction variability across trials. This superiority in estimating such short time intervals can be attributed to the enhanced perceptual and motor abilities

from a sustained practice of extremely fast movements. Indeed, sport training has been proved to induce adaptive functional and structural changes in the motor-related systems (Jacini et al. 2009; Wei et al. 2011). In a similar vein, professional pianists and percussionists' exceptional time evaluation have been observed particularly for brief time intervals, proving that they possess highly refined sensory motor system developed from musical training (Chen et al. 2013; Cicchini et al. 2012). Interestingly, similar result is also found in chronic video game players as compared to casual video game players (Rivero et al. 2013). That is, chronic players perceive the time more precisely than casual players in the sub-second range tasks, while such difference was absent for the multi-second tasks. These results support the idea that when dealing with time estimation individual differences need to be taken into account (review see Hancock and Block 2012).

Moreover, it is important to consider whether studies aimed to assess participants' time estimation ability have been performed by applying a 'time reproduction' or a 'time discrimination' task (Grondin 2010). While time discrimination is a pure perceptual task, time reproduction is a perceptual and motor combined task. Here, a time reproduction task has been selected to test the influences of different levels of sensory motor sensitivity in timing. Our results showed that it is possible to adjust the distortion by having higher sensory motor sensitivity.

Finally, we should acknowledge that we expected pole-vaulters to show their superiority particularly for the familiar pole-vault image as we found in our previous results (Chen et al. 2013). Interestingly, though, pole-vaulters revealed the same level of accuracy and stability for all images. The inconsistency between the two studies could be related to the level of details of the body part presented: For the pianists, the image observed was a hand, while pole-vaulters observed the entire body. As a result, the zoomed and enlarged hand might have more easily induced an internal simulation permitting better time estimates. Nevertheless, pole-vaulters could better recall the features presented in the pole-vault image, while no such expertise effect was found when pole-vaulters recalled the features presented in fencing lunge image and in scrambled pixels. We interpreted their better recall for pole-vault jump image due to their greater allowance of working memory capacity to notice the features contained in the familiar action even if they were not explicitly requested to recall features from the image but to perform a time reproduction task.

In sum, we provide the evidence that our estimate for brief times is compressed, while a highly dynamic action is observed. Elite athletes can compensate for this bias and be less erroneous and variable in their estimations, suggesting that their internal clock for brief timescales has been refined through sport training.

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