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Off-line authorship effects in action perception

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Abstract

Does the perception of our actions differ from the perception of other individuals' actions when we observe them, like other individual's actions, in an offline perspective? Previous studies, using recognition as well as prediction judgments, suggest that it does even if the stimulus information is reduced to a single moving point-light. Here, we assessed whether this difference also affects the timing of actions. This was tested in two experiments, using a specific synchronization task. After some practice, self-generated action events were anticipated faster than other action events, provided that the anticipation could not be accomplished sufficiently well on the basis of easily detectable cues. The results are discussed with regard to the previous findings of off-line authorship effects in action perception.

Keywords: Authorship; Action perception; Synchronization; Self-other discrimination; Point-light display; Anticipation

1. Introduction

Action perception usually occurs in two varieties. Either we perceive another individual acting, or we perceive ourselves acting. Regularly, these cases are analyzed separately, the former in the domain of perception research and the latter in the domain of action research. In the following, we will try to relate them. Particularly, we suggest that both varieties of action perception are mediated by anticipatory processes, which rely on action-related representations. Thus, it is conceivable that the perception of a human movement—be it one's own or somebody else's—allows for the anticipation of the action goal. The assumption that action-related processes contribute to action perception seems to imply that perceiving one's own actions might be special compared to perceiving somebody else's actions. Before we report two experiments addressing this issue, we will provide a short overview of relevant prior research.

One way to investigate the perception of human movements is given by the point-light technique, which was introduced by Johansson (1973). Marking the main joints of the human body with point-lights, he filmed individuals walking to and fro in front of the camera. When the stationary set of point-lights was displayed, observers did not recognize a human body. The moment the point-lights moved, however, observers immediately recognized a human movement (cf. also Johansson, 1976). Subsequent studies have shown that these point-light displays can be used to identify the walker's sex (cf. Kozlowski & Cutting, 1977), the intention to deceive the observer about the walker's sex (cf. Runeson & Frykholm, 1983), or the emotion expressed in dance (cf. Dittrich, Troscianko, Lea, & Morgan, 1996). It should be noted that point-light displays also allow for the identification of the identity of the walker (cf. Cutting & Kozlowski, 1977), which may be even better when the individual observes her- or himself than when he or she observes an acquaintance (cf. Beardsworth & Buckner, 1981). This is remarkable, because, in this study, the participants had observed their acquaintances more often from a third-person perspective than themselves.

Point-light displays of human locomotion have attracted much interest because they provide a case in point in which motion and form information interact

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(cf. Oram & Perrett, 1994). The fact that they also represent a special type of motion, namely one that can be generated by the observers themselves has so far received less attention. Indirect evidence for a contribution of action-related processes is provided by the fact that the perception of point-light displays of human locomotion is accompanied by neuronal activity in cerebellar structures (cf. Grossman et al., 2000) that are also activated during action generation.

More direct evidence for an influence of action-related processes on motion perception comes from studies using single point-lights. In these studies, human movements are no longer specified by the configuration of point-lights. Instead, they are specified by constraints that are characteristic for human movements. For instance, drawing movements can be described by the two-thirds power law (cf. Lacquaniti, Terzuolo, & Viviani, 1983), which is given by a specific covariation between the instantaneous velocity and the radius of curvature of the movement's trajectory. Importantly, this motor constraint also affects motion perception. Thus, the perception of the eccentricity of an ellipsoid motion is biased by its instantaneous velocity, in a way that is predicted by the two-thirds power law (cf. Viviani, Baud-Bovy, & Redolfi, 1997). Correspondingly, the perception of the uniform velocity of a respective motion depends on the compliance with the motor constraint under investigation (cf. Viviani & Stucchi, 1992).

Moreover, there is also some evidence that action-related processes contribute to the prediction of a forthcoming action event. In handwriting, so-called coarticulation effects are given by the fact that a subsequent letter may affect the spatio-temporal characteristics of the generation of the current letter (cf. Thomassen & Schomaker, 1986). Orliaguet, Kandel, and Boe (1997) then showed that these coarticulation effects can be used in a perceptual judgment task. In their study, subjects predicted the second letter of a two-letter sequence after having observed the first letter. When just the form of the first letter was displayed, prediction accuracy was not above chance. When the emerging trace of the letter was displayed, however, prediction accuracy was significantly better. Finally, prediction accuracy remained comparably high when form differences between the letters were eliminated. Subsequently, Kandel, Orliaguet, and Viviani (2000b) showed that the prediction performance in this kind of task depends on the compliance of the displayed motion with the two-thirds power law. Finally, Chaminade, Meary, Orliaguet, and Decety (2001) found that this perceptual anticipation is accompanied by a neuronal activation that is also found in action generation. Taken together, the studies reviewed so far suggest that action-related representations contribute to action perception.

2. Authorship in action perception

One way to extend the evidence for action-related contributions to perception is to investigate how authorship affects action perception. Authorship in our definition refers to the distinction between observing one's own actions and their consequences and observing somebody else's actions and their consequences. By authorship effects we refer to differences in perception and performance that are due to the fact that some action effect has been self-generated and not generated by somebody else.

Most of the time, the perception of one's own actions is quite different from the perception of another individual's actions in several regards. On the one hand, some action-related information is only amenable to the individual generating the action. This ranges from the optic flow that specifies the instantaneous position of the moving observer (cf. Gibson, 1979) to the proprioceptive signals which are provided by the muscle spindles and the tendon organs (cf. Greer, 1984). On the other hand, there are diverse action planning processes that precede the execution of the action (cf. Jeannerod, 1994). One of these action planning processes is given by a prediction of the sensory effects of the movement (cf. Wolpert, Ghahramani, & Jordan, 1995). Accordingly, Blakemore, Frith, and Wolpert (1999) suggested that the perception of a self-generated action effect differs from the perception of another action effect with regard to the spatio-temporal accuracy of the effect anticipation.

Crucially, differences in the spatio-temporal accuracy of effect anticipation may also occur for the perception of action effects, which have been generated at an earlier point of time. Thus, self-generated action effects do not differ any longer from other action effects with regard to proprioceptive signals. In the following, any significant difference that emerges between the perception of one's own action effects and the perception of other action effects will be called authorship effect. Given that the generation of these action effects are temporally separated from their perception, these significant differences will be called offline authorship effects.

In order to be able to obtain authorship effects in the offline perception of self-generated and other-generated action effects, several requirements have to be met. On the one hand, one has to ascertain that the action effects are inter-individually variable—specifically, the inter-individual variability has to outnumber the intra-individual variability of the action effects in question. Moreover, this inter-individual variability should refer to inter-individual differences in central representations. In other words, it should not rely on anatomical differences or on differences in motor variability. On the other hand, one has to take care of the fact that a better anticipation of self-generated action effects does not derive from the fact that only the subject who generated the action effect can remember the episode of its generation. One way to deal with the latter demand is to reduce the number of possible cues for remembrance. Moreover, the remaining cues should refer to a movement parameter that is controlled in action generation. Then, one may conclude that an off-line authorship effect in action perception is mediated by inter-individually different action representations.

One piece of evidence for off-line authorship effects in action perception can be found in the earlier mentioned study of Beardsworth and Buckner (1981). Their study does not indicate, however, on which cues self-recognition relied on. In order to increase the chance to identify those cues that are used for self-recognition, one may reduce the stimulus display to a single moving point-light, describing the kinematics of a handwriting—or more generally: drawing—movement. Handwriting is assumed to be specific to the individual having generated it (cf. Merton, 1972). Some evidence for this assumption is provided by studies addressing the problem of automatic signature verification (cf. Plamondon & Lorette, 1989). Interestingly, verification systems using dynamic information have been more efficient than verification systems using only static information (cf. also Leclerc & Plamondon, 1994). This suggests that inter-individual differences in handwriting could be partly rooted in the way the handwriting movements are generated.

Further evidence for offline authorship effects in the handwriting domain has been provided in a study by Knoblich and Prinz (2001). In a first session, they instructed subjects to draw different symbols on a graphic tablet. In a test session, subjects observed their own drawing movements as well as corresponding drawing movements of another subject, reproduced by a single point-light. The percent correct (PC) score of the self-recognition judgments amounted to 59%, which is significantly above the chance level of 50%. The scaling of the self-generated and the other-generated trajectories to a common size and overall duration did not change the results. Moreover, it did not matter whether or not the symbols were familiar. Reproducing the drawings with a constant velocity, however, eliminated the authorship effect. These results suggest that inter-individual differences in velocity variations—such as the relative durations of the acceleration phases and the deceleration phases—are crucial for a self-attribution of action effects.

The study of Orliaguet et al. (1997) suggests that action-related representations can also be used for the prediction of a forthcoming action event. Thus, Knoblich, Seigerschmidt, Flach, and Prinz (2002) instructed subjects to draw complete and incomplete "2"—figures in a first session—in the latter case, only the first stroke should be drawn. In the test session, the subjects observed the first stroke of each movement, reproduced by a moving dot, and judged whether or not it had been generated as part of the complete figure "2." The accuracy of prediction was significantly above chance when the movements were generated by the observing subjects themselves, but not when they were generated by another subject. This observation suggests that the cues that allowed subjects to correctly predict an forthcoming action event, were only detected or used by the subjects who had generated the movement themselves.

Finally, Knoblich and Flach (2001) showed that authorship effects in a prediction task can also be found in a more natural setting. In the recording session, subjects threw darts on a target board that was divided into thirds of equal height. In the test session, subjects observed videos showing their own or another subject's throws until the moment the dart left the hand. They indicated whether the dart had been propelled to the upper, middle, or lower third of the board. The prediction accuracy was above chance in all conditions. Moreover, the prediction accuracy increased with the serial position of the block of the test session, given that the displayed movements had been self-generated. One way to account for the latter observation is given by the assumption that not all the information contributing to the prediction task at hand was available from the start. Instead, this information had to be derived from the visual displays, which could only be realized for self-generated movements.

3. Does authorship affect the anticipated timing of action effects?

The latter two prediction studies differ from the former recognition study with regard to the fact that the subjects had to engage in some kind of anticipation. In the study of Knoblich et al. (2002), subjects had to predict what kind of action event would come next. In the study of Knoblich and Flach (2001), subjects had to predict the intended end position of the unfolding action. Both studies did not address the timing aspect of the response. However, the timing of actions is crucial in the generation of many everyday actions. Take handshaking as an example. When observing the person opposite stretching out his or her hand, one usually initiates the corresponding movement before the observed movement comes to a halt. Doing this, one probably relies on an anticipation of the location and time of hand contact. Thereby, the handshaking becomes a relatively smooth interpersonal coordination.

In order to assess whether the representations underlying off-line authorship effects are also used in action generation, we looked for a task that requires anticipating the time of a forthcoming action event. The standard task used to assess anticipatory timing of events is the synchronization task (cf. Aschersleben, 1994). In this task, subjects have to synchronize their own movements with a more or less predictable sequence of external events. These external events usually consist in a regular sequence of auditory signals. The external events used in the subsequent experiments consisted in the points of minimum radius of curvature—i.e., the points of most salient direction change—within a visual display of continuous drawing movements, which can be assumed to be specified in advance in movement generation (cf. Viviani & Flash, 1995). The drawing movements were either generated by the subjects themselves or by another subject.

Such continuous drawing movements provide a wealth of potential cues for anticipating the timing of crucial action events. It is likely that these cues are related to action generation and that some of these cues are specific to the person who produced the movement he or she needs to synchronize with. Thus, if action representations contribute to action perception and if these representations also specify the timing of action events one would expect that authorship affects the anticipated time of crucial action events. However, it cannot be specified a priori on which cues these anticipations are based. Nevertheless, it is possible to derive various parameters from the drawing movements and to determine post-hoc which of them are most likely to selectively inform temporal anticipations of the author, that is, the person who generated the movement.

4. Experiment 1

This experiment addressed the question whether synchronizing with action effects depends on the similarity between the perceived effect and the way the corresponding actions are generated. For this purpose, the synchronization performance for self- and other-generated action effects was compared. More precisely, each subject observed self-generated action effects as well as action effects generated by another subject. Two subjects were matched, respectively, so that both responded to exactly the same stimuli. Therefore, any influences of authorship on synchronization performance cannot be explained by stimulus variables alone.

However, there have to be some stimulus variables that covary with the presence of an authorship effect. If the self-generated and other-generated stimuli were identical, authorship could not affect synchronization performance. Yet, it is hardly possible to know a priori exactly which stimulus variables moderate authorship effects. It thus appears advantageous to use different forms for copying that are likely to affect performance. In particular, the subjects reproduced a sequence of strokes, which were concatenated by five peaks and dips. Either the direction changes at the peaks and dips occurred continuously, as in the wave patterns displayed in Figs. 1B and D, or they occurred abruptly, as in the zigzag patterns displayed in Figs. 1A and C. Because abrupt direction changes in writing require that the movement temporally comes to a halt the velocity changes within each stroke should be more salient for the zigzag pattern. If an authorship effect relies on information about velocity changes within a stroke, an interaction between authorship and form is expected.

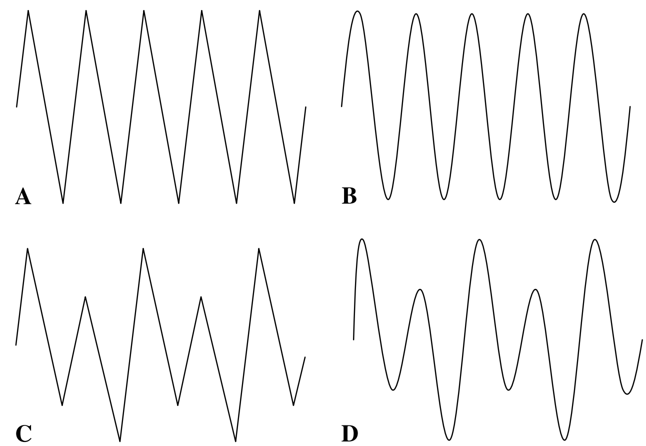

Fig. 1. Stimulus patterns used in Experiment 1. A and B are the regular forms, C and D are the irregular forms. A and C are the zigzag forms, B and D are the wave forms.

Additionally, the regularity of the peaks' and dips' height was varied. Either all peaks and dips had the same height (see Figs. 1A and B) or their height alternated (see Figs. 1C and D). In the latter case, the length of the upstrokes varied correspondingly. In the former case, the spatio-temporal occurrence of a peak may be more easily estimated upon the spatio-temporal occurrence of the previous peak. If an authorship effect relies on information about the strokes' length, we can expect an interaction between authorship and regularity.

4.1. Method

4.1.1. Subjects

32 subjects took part in the experiment, 12 of them male. They ranged in age from 21 to 42 years. All subjects had normal or corrected-to-normal vision. They received payment for their participation.

4.1.2. Apparatus and stimuli

Four patterns were used as stimuli during the recording session (see Fig. 1). All patterns had five peaks and five dips. They differed with respect to the form near the individual peaks and dips. They described either a zigzag pattern or a wave pattern. Moreover, they differed with respect to the regularity of the peaks' and dips' height—and, therefore, with respect to the regularity of the upstrokes' lengths. Either all peaks and dips had the same height or every second peak and dip had the same height (cf. Fig. 1). In the case of the regular zigzag pattern, the length of the individual strokes amounted to 21.82 cm—the first and the last upstroke had a length of 10.91 cm. The enclosed angles amounted to 0.27 rad. In the case of the irregular zigzag pattern, the length of the upstrokes alternated between 11.21 and 21.82 cm—the length of the downstrokes was always 16.48 cm. The enclosed angles alternated between 0.32 and 0.46 rad. In the case of the regular wave pattern, the eccentricity amounted to 0.99. In the case of the irregular wave pattern, the eccentricity was about 0.97. The wave patterns had the same extensions as the zigzag patterns. All patterns were displayed as complete forms.

The visual stimuli were displayed on two Apple 17″ monitors with a spatial resolution of 832×624 pixels; the vertical sync frequency was 100 Hz. The movements were recorded by a WACOM 2.5.5-D digitizer tablet with the size of $45.72\,\text{cm} \times 30.48\,\text{cm}$; the spatial resolution was $22{,}860 \times 15{,}240$ pixels; the sampling rate was 100 Hz. The mapping between the graphic tablet and the screen was 1:1.

During the test session, subjects viewed the movements displayed by a black dot moving in front of a white screen; the diameter of the dot was about 0.38 cm. Viewing distance was unrestrained at a distance of about 50 cm from the screen. The room light was dimmed. The responses were recorded with a PsyScope button box (cf. Cohen, MacWhinney, Flatt, & Provost, 1993).

4.1.3. Procedure

Each subject passed two sessions. During the recording session, the subjects generated twelve reproductions of each of the four patterns. At the outset, the subjects became familiarized with the drawing utensils and the experimental procedure. Each trial started with the display of the respective pattern. As soon as the subjects increased the pen pressure above a fixed limit, the pattern disappeared and the subjects had 10 s to reproduce it. The emerging trace was displayed on the second screen, which was not visible for the subject. The experimenter decided whether the reproductions were appropriate. The subjects did not receive any visual feedback. Furthermore, both the tablet and the moving hand were screened from view. The recording session lasted about 30 min.

The movements produced during the recording session were selected as stimuli for the test session if they were continuous, had the characteristic form, and had five peaks. The first criterion was violated when the recording had been interrupted—e.g., when a subject lifted the pen. The second criterion was violated when the curves could not be distinguished easily from corners, or, more frequently, when the height of the peaks did not clearly alternate. The criteria were confirmed by visual inspection.

The 10 most suitable reproductions for each pattern were chosen for the test session. Those reproductions were combined with an equal number of reproductions generated by another randomly chosen subject. Both subjects observed the same stimuli in the same pseudo-random order. Self-generated and other-generated movements were displayed as often at the beginning as at the end of a block. The movements were displayed kinematically: The subjects saw a moving dot reproducing their own or the other subject's drawing movements. This dot did not leave a trace on the computer monitor. They were instructed to press a key at the exact point in time at which the dot reached a peak. This was done five times within a trial. If the subjects omitted a peak or if their reactions occurred more than 400 ms too soon or too late, they were given an error feedback and the trial was repeated immediately. In total, there were three blocks with 80 trials each. The subjects started each trial on their own. The test session lasted about an hour.

4.1.4. Movement description

On the average, the movements were about 141.2 cm long ($s = 28.9$ cm), their duration was 9.01s ($s = 0.98$ s). The horizontal extension was 26.1 cm ($s = 3.3$ cm), and the vertical extension was 16.7 cm ($s = 3.1$ cm). An upstroke lasted 0.80 s ($s = 0.20$ s) and had a length of 12.7 cm ($s = 4.6$ cm). A peak occurred 0.42 s ($s = 0.17$ s) after the maximum velocity of the upstroke—this duration is subsequently called deceleration phase.

The mean lengths of the movements for individual subjects varied between 86.0 and 179.4 cm. The mean durations varied between 7.59 and 9.83 s. The mean horizontal extension varied between 21.9 and 29.5 cm. The mean vertical extension varied between 10.2 and 20.7 cm. The individual mean durations of the upstrokes varied between 0.67 and 0.96 s. The mean upstroke lengths varied between 7.2 and 15.8 cm. Finally, the individual mean deceleration phases varied between 0.36 and 0.72 s.

4.1.5. Data analysis

A normally distributed variable can be sufficiently described by the constant error and the variable error (cf. Schutz & Roy, 1973). Both measures were analyzed. Since the variable error turned out to be less sensitive than the constant error and since it did not provide additional insights, the report of the results will be restricted to the constant error. It consisted in the arithmetic mean of the temporal deviations between the onsets of the key presses and the times of occurrence of the respective peaks, summed over the five peaks of an exemplar as well as over the 10 exemplars of a form.

4.2. Results

Less than 5% of all trials had to be repeated. Because the responses in repeated trials did not differ significantly from the responses in unrepeated trials, they were included in the analysis. All reported effects are significant at a level of 5%.

Fig. 2 displays the results of Experiment 1. A $2 \times 3 \times 2 \times 2$-ANOVA of the constant error with the within-subjects factors authorship (self vs. other), block (1, 2, and 3), form (corners vs. curves), and regularity (regular vs. irregular), revealed significant main effects of block ($F(2, 62) = 13.72; p < .01$), form ($F(1, 31) = 10.73$; $p < .01$), and regularity ($F(1, 31) = 6.94$; $p = .01$). Furthermore, there were significant interaction effects between block and regularity ($F(2, 62) = 3.64; p = .03$) and between block, regularity and authorship ($F(2, 62) = 3.34$; $p = .05$). No other effect approached significance.

The average constant error was +41 ms—the average variable error was 110 ms. As shown by post-hoc Scheffé tests, the constant error was more positive in the 1st block (+59 ms) than in the 2nd block (+35 ms) or in the 3rd block (+30 ms). It was more positive for the wave form (+50 ms) than for the zigzag form (+32 ms), and for the irregular line drawings (+45 ms) compared to the regular ones (+37 ms). The two-way interaction between block and regularity could be traced back to the fact that the difference between regular and irregular patterns was only significant for the first two blocks. Finally, the three-way interaction was traced back to the fact that the constant error was lower for self- than for other-generated movements of irregular patterns during the third block (cf. Fig. 2). In order to assess whether this effect is only present for a few subject pairs, we calculated the difference between the constant errors for other-generated movements and the constant errors for self-generated movements as an index of the authorship effect for less regular movements in the third block. This index was positive for 12 out of 16 pairs of subjects.

4.3. Discussion

First of all, the synchronization performance was not very accurate. Yet, some anticipation of the forthcoming direction change took place—as indicated by the average constant error. Nonetheless, no main effect of authorship emerged. Thus, the crucial spatiotemporal information that was used for the anticipation of the forthcoming direction change does not seem to belong to the action representation or is not specific to the author of the movement, initially. Rather, the main effect of block suggests that the subject still had to identify those movement parameters that were predictive for the forthcoming direction change. Some of these parameters were amenable to all subjects—irrespective of the authorship of the stimulus movements. The results provide also some evidence that some parameters were only amenable to the authors of the movements.

The main effect of regularity suggests that the height of the previous peak or the length of the previous upstroke, respectively, provided a more or less reliable cue for predicting the forthcoming direction change. Since the subjects also accomplished to synchronize with the irregular movements to some degree, this parameter does not seem to be the only one used for the task at hand. Instead, there also have to be other predictive cues. These cues might have been less reliable, however. Thus, they might only have affected timing performance when synchronizing with irregular movements. Moreover, they might have been amenable only to those subjects having generated the displayed movement. The question which movement parameters might have played this role will be discussed subsequent to the report of Experiment 2.

5. Experiment 2

The primary aim of the second experiment was to replicate the results obtained in the previous experiment. Besides, it aimed at assessing whether the authorship effect, qualified by block and regularity,

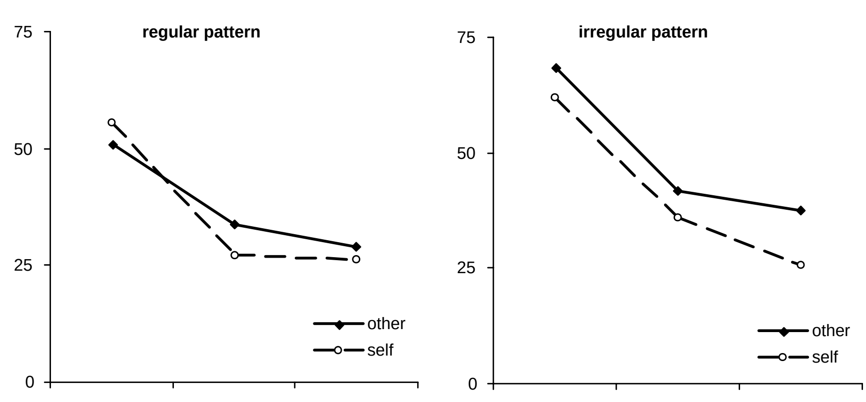

Fig. 2. Constant errors (in ms) in Experiment 1. On the left, the constant errors for the regular patterns are shown. On the right, the constant errors for the irregular patterns are shown. The full lines indicate the constant errors for other-generated motions, the dashed lines those for self-generated motions. The abscissae indicate the serial position of the block.

implies a difference in temporal accuracy. Since we relied on the constant error as the main dependent variable, it is not clear whether the observed effect depends on the absolute level of the constant error. Actually, some subjects tended to respond too early, whereas some tended to respond too late. However, an informal inspection of the differences between the responses to other- and self-generated less regular movements in the third block for each pair of subjects in the first experiment did not suggest a dependence of the effect on the absolute level of the constant error. A quintile analysis of the individual responses of each subject in Experiment 1 confirmed this conclusion. Thus, we predicted that the same qualitative pattern of results emerges when the overall level of the constant error of synchronization is shifted. For this purpose, 10 practice trials were introduced at the beginning of the test session. In those trials, the subjects received error feedback if the average constant error for the responses within a trial was negative. In consequence, the subjects generally responded later. During the experimental trials, they did not receive error feedback.

Additionally, there were several minor modifications: Most importantly, the stimuli were restricted to irregular patterns and a fourth block was added to the test session. The rationale for the first modification was that, in Experiment 1, authorship effects were only present for irregular patterns. The second modification aimed at determining the nature of the interaction between authorship and block in the previous experiment. If the interaction is due to a faster drop of the constant error for self-generated stimuli—manifested in the slope of the curve—it should disappear in the long run. If it is due to the lower level of the asymptotic constant error for self-generated stimuli—manifested in the intercept of the curve—the authorship effect should also be observed for the additional block.

5.1. Method

5.1.1. Subjects

Thirty-two subjects took part in the experiment, 7 of them male. They ranged in age from 19 to 42 years. All subjects had normal or corrected-to-normal vision. They received payment for their participation.

5.1.2. Apparatus and stimuli

Two line drawings were used as patterns. These were the same as the irregular ones in the previous experiment, except that they consisted of six peaks and dips. In the case of the zigzag pattern, the length of the upstroke alternated between 11.09 and 21.76 cm—the first upstroke had a length of 10.88 cm; the length of the downstrokes always amounted to 16.40 cm. The wave pattern had the corresponding extensions.

5.1.3. Procedure

There were two sessions. During the recording session, the subjects generated 15 reproductions of each of the two line drawings (see Figs. 1C and D). The same criteria as in the first experiment were used to select 10 suitable reproductions of each form.

The subjects started the test session with 10 practice trials. During these trials, an artificial movement with a sinusoidal acceleration profile was displayed. The form of these movements alternated between angular and curved. If the subjects reacted on the average too early within a trial, they received a respective error feedback, and the trial was immediately repeated. This error feedback was only provided in the practice trials. Subsequently, the subjects completed four blocks—each block now encompassing 40 trials. Except for the presentation of the zigzag and the wave forms now alternating, the procedure was the same as in the previous experiment.

5.1.4. Movement description

On the average, the movements were about 135.5 cm long ($s = 35.1$ cm), their duration was 10.01 s ($s = 1.71$ s). The horizontal extension was 24.5 cm ($s = 4.6$ cm), and the vertical extension was 15.5 cm ($s = 3.8$ cm). An upstroke lasted 0.70 s ($s = 0.16$ s) and had a length of 9.7 cm ($s = 2.6$ cm). The deceleration phase lasted 0.43 s ($s = 0.14$ s).

The mean lengths of the movements for individual subjects varied between 65.5 and 200.2 cm. The mean durations varied between 6.76 and 11.81 s. The mean horizontal extension varied between 13.7 and 29.9 cm. The mean vertical extension varied between 8.0 and 21.9 cm. The individual mean durations of the upstrokes varied between 0.43 and 0.92 s. The mean upstroke lengths varied between 4.6 and 14.4 cm. Finally, the individual mean deceleration phases varied between 0.25 and 0.60 s.

5.1.5. Data analysis

The same dependent variable was used as in the first experiment. Again, the responses were collapsed over the six peaks of an exemplar as well as over the 10 exemplars of a form.

5.2. Results

All in all, 14% of the experimental trials had to be repeated. Once more, the responses during repeated trials did not differ significantly from the responses during unrepeated trials. Thus, they were included in the analysis.

Fig. 3 shows the results of Experiment 2. A $2 \times 3 \times 2$-ANOVA of the constant error with the within-subjects factors authorship (self vs. other), block (1, 2, 3, and 4), and form (corners vs. curves) revealed significant main

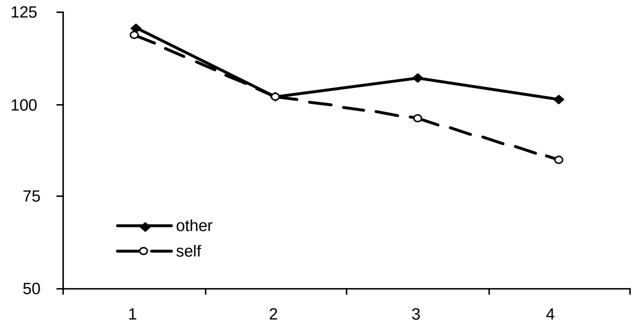

Fig. 3. Constant errors (in ms) in Experiment 2. The full lines indicate the constant errors for other-generated motions, the dashed lines for self-generated motions. The abscissa denotes the serial position of the block. It should be noted that the ordinate depicts a different range of the constant error than in the previous experiment.

effects of block ($F(3,93) = 7.13$; $p < .01$) as well as a significant interaction effect between authorship and block ($F(3,93) = 2.67$; $p = .05$). No other effect approached significance.

The average constant error was +104 ms—the average variable error was 114 ms. As shown by post-hoc Scheffé tests, the constant error was more positive for the 1st block (+126 ms) than for the 2nd block (+105 ms), the 3rd block (+103 ms), and the 4th block (+97 ms). The authorship-block interaction effect was traced back to the fact that the difference between self-generated and other motions was only significant for the 3rd and the 4th block (cf. Fig. 3). Using the difference between the constant errors for other-generated movements from the constant errors for self-generated movements in the third and fourth block as an index of the authorship effect, this index was positive for 12 out of 16 pairs of subjects.

5.3. Discussion

The second experiment provides a conceptual replication of the previous results. First of all, the displacement of the absolute level of performance ($t(30) = 3.78$; $p < .01$) did not change the qualitative pattern of results. Accordingly, an authorship effect only occurred in later trials. Moreover, it did not diminish in the fourth block. Thus, one may tentatively conclude that an authorship effect in synchronization is not just a temporary phenomenon. In any case, the results support the assumption that the authorship effect does not depend on the absolute level of the constant error. Again, a quintile analysis of the individual responses confirmed this conclusion.

One way to account for this observation is given by the following line of reasoning. While observing the unfolding movement, the subjects have to detect cues that can be used to anticipate the forthcoming direction change. Again, these cues seem to be related to the individual strokes. Importantly, the predictive validity of these cues is not perfect. The only perfectly valid cue is the forthcoming direction change itself—however, the subjects could not rely on this cue without responding much too late. Conceptualizing the influence of all these cues in an accumulating function of response certainty, we also have to assume a response criterion, which can be influenced by different variables. One of these variables may be the response strategy—for instance, the subject may try more strongly to avoid too early responses than too late ones. The fact that the authorship effect did not depend on the absolute level of the constant error then provides some evidence that authorship primarily influenced the accumulative function of response certainty—i.e., the prediction of the forthcoming direction change itself.

6. Which parameters of a movement are specific for a given individual?

In order to further qualify the authorship effects in Experiment 1 and 2, we conducted two additional analyses. In a first step, we assessed whether the movement parameters underlying an authorship effect in synchronization derive from global or from more local aspects of a movement. Whereas global aspects refer to the whole movement, more local ones refer—in our case—to individual strokes. For this purpose, we analyzed whether the authorship effect varied depending on the serial position of the peak. If the authorship effect rely on global movement aspects, the difference between self-generated and other stimuli should increase with the serial position of the peak. If the authorship effect relies on the more local aspects, authorship should not interact with the serial position of the peak. The results displayed in Fig. 4 support the latter assumption (Experiment 1: $F(4,124) = 0.01$; $p = 1.00$; Experiment 2: $F(5,155) = 0.46$; $p = .81$).

This finding may not be too surprising given that events occurring in close temporal proximity to a target event possess a higher predictive validity because there are less intervening events that may interfere. One such event may be the starting point of the upstroke—i.e., the dip before the peak. The anticipation of the following peak could then be based on an estimate of the upstroke durations, which is functionally related to the lengths of the upstrokes and their maximum velocities (cf. Edelman & Flash, 1987; Hogan & Flash, 1987). To the extent that the upstroke lengths and maximum velocities are constant across the strokes of a movement, this information may be provided by the respective parameter values of the preceding strokes. This may explain the fact that no authorship effect could be observed for regular patterns in Experiment 1. To the extent that these parameter values do not turn out to be predictive,

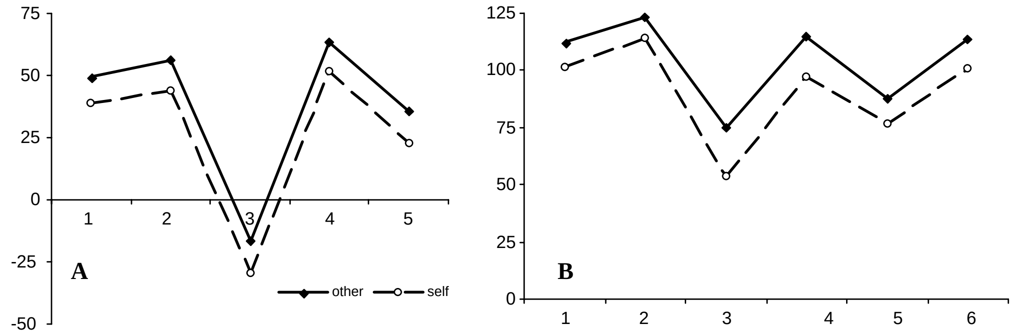

Fig. 4. The authorship effect as a function of the serial position of the peak. Panel A shows the constant errors (in ms) for irregular patterns in the third block of Experiment 1. Panel B shows the constant errors (in ms) in the third and fourth block of Experiment 2. The full lines indicate the constant errors for other-generated motions, the dashed lines for self-generated motions. The abscissa indicates the serial position of the peak.

subjects may draw on an internal estimate of the local parameters. In other words, their anticipation may rely on the way they would generate the observed movement.

Given that the estimates of the upstroke lengths are derived from an internal representation, the maximum velocity still has to be specified in order to predict the upstroke durations. The easiest way to specify this parameter value is given by its observation. This strategy presupposes, however, that the temporal position of the maximum velocity occurs sufficiently remote from the criterion event. Only then, its perception can be used to initiate the synchronization response in time. If this reasoning holds true, authorship effects should only be observed for longer deceleration phases. For this purpose, the responses referring to individual peaks were categorized into quintiles according to the duration of the deceleration phases of the respective upstrokes, and the average constant errors were calculated for self- and other-generated movements for each quintile. As can be seen in Fig. 5, the authorship effect tended to be larger for longer deceleration phases. This is consistent with the assumption that subjects base their anticipation of the forthcoming peak on the detection of the spatio-temporal position of the upstroke's maximum velocity (cf. also Kandel, Orliaguet, & Boe, 2000a, 2000b), which might be easier for self-generated movements.

7. General discussion

In two experiments, we found evidence that synchronizing with one's own action effects is different from synchronizing with somebody else's action effects. After some practice, subjects began to respond earlier to self-generated than to other-generated action effects. This authorship effect only occurred when the motion stimuli were rather unpredictable. Finally, post-hoc analyses suggested that the authorship effect was mediated by local movement parameters.

The result that synchronization responses occurred earlier for self-generated movements provide some evidence that the temporal anticipation of action events can be affected by cues that are related to the way a specific person generates a movement. This difference in anticipatory timing may be traced back to the fact that individuals are better at detecting those motion cues that

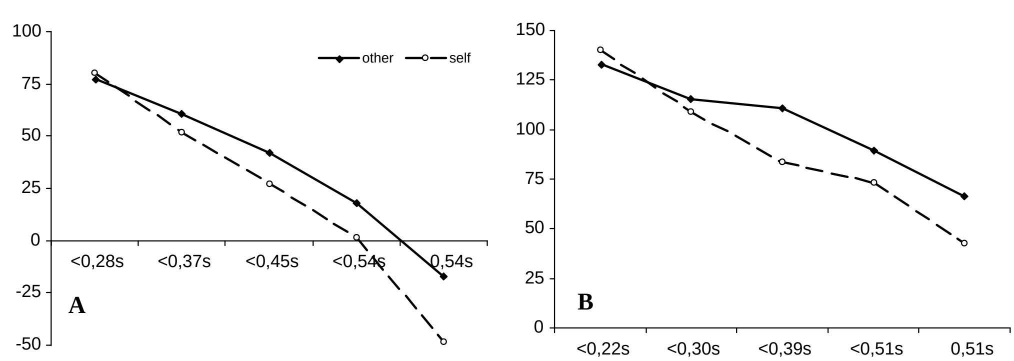

Fig. 5. The authorship effect as a function of the duration of the upstrokes' deceleration phases. Panel A shows the constant errors (in ms) for irregular motions in the third block of Experiment 1. Panel B shows the constant errors in the third and fourth block of Experiment 2. The full lines indicate the constant errors for other-generated motions, the dashed lines those for self-generated motions. The abscissa denotes the quintiles of the deceleration phases—e.g., in the first quintile in Panel A, the deceleration phases lasted less than 0.28 s, and so on. The data points of each quintile are based on the same number of responses to self- and other generated motion stimuli.

are predictive for the forthcoming direction change, or it may be attributed to the fact that they can better use this information for the demanded anticipation. In any case, the result that the difference was not present right from start indicated that predictive cues had to be detected or their correct use had to be learned in the first place. This contrasts with earlier results obtained in a recognition task (Knoblich & Prinz, 2001) as well as a prediction task (Knoblich et al., 2002), in which authorship effects were immediately present.

It is tempting to relate this contrast between the recognition or identification task and the synchronization task to studies allegedly showing a dissociation between perception and action measures (cf. Bridgeman, 1992; Milner & Goodale, 1995; Neumann & Klotz, 1994). Thus, one may speculate that the off-line authorship effects are primarily mediated by perceptual representations. In contrast, the synchronization responses may rely on motor representations. Recently, it has been suggested that the dissociation between perception and action measures may be partly rooted in the difference between fast and rather slow responses (cf. Bridgeman, 2000; Pisella & Rossetti, 2000). This speed difference may reflect different amounts of information processing. In particular, perceptual responses—such as the recognition or identification of an action effect—may presuppose the build-up of an internal representation. This demand could be accounted for by the use of unspeeded judgments. In contrast, motor responses—such as synchronization—may just presuppose a parameter specification.

In the present case, the perceptual input only had to indicate the correct time of initiating the response. One candidate for this information may be given by the beginning deceleration of the upstroke motions. Crucially, the detection of this motion cue might benefit from the previous build-up of an action representation, enabling the anticipation of, for instance, the spatio-temporal position of the maximum velocity (cf. Kandel et al., 2000a, 2000b) on the basis of the estimated upstroke lengths and upstroke durations. Assuming that building up an action representation or relating the perceived movement parameters, respectively, takes some time could then account for the observation that an authorship effect in synchronization did not occur immediately.

One may wonder whether the delayed effect of authorship on the synchronization responses can be reconciled with the view that the perception of an action effect as self-generated automatically accompanies everyday action perception. Taking imitation as an example, one may point out that the imitated action is usually relatively complex—at least, more complex than pressing a single key (cf. Braß, 2000; Stürmer, Aschersleben, & Prinz, 2000). Thus, it will regularly not suffice to specify a single parameter. Instead, an integrated action representation presumably mediates between the perception of the to-be-imitated action and the temporally delayed execution of the imitated action. Moreover, off-line authorship effects in action perception corroborate the general assumption that the transformation of the sensory input into the motor output can be mediated by action effect representations even when—as in imitation—the perception and the generation of the action effect are temporally separated. One may thus assume that the imitating actions of several individuals, observing the same action, will reveal predictable inter-individual differences. Future studies may show whether these hypotheses hold true.

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