

This article was downloaded by: [UNAM Ciudad Universitaria]

On: 25 April 2014, At: 21:23

Publisher: Routledge

Informa Ltd Registered in England and Wales Registered Number: 1072954 Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK



## Journal of Cognitive Psychology

Publication details, including instructions for authors and subscription information:

<http://www.tandfonline.com/loi/pecp21>

### Action perception via auditory information: Agent identification and discrimination with complex movement sounds

Christian Kennel<sup>a</sup>, Tanja Hohmann<sup>b</sup> & Markus Raab<sup>a</sup>

<sup>a</sup> Institute of Psychology, German Sport University Cologne, Cologne, Germany

<sup>b</sup> Department of Sport and Exercise Science, University of Stuttgart, Stuttgart, Germany

Published online: 24 Dec 2013.

To cite this article: Christian Kennel, Tanja Hohmann & Markus Raab (2014) Action perception via auditory information: Agent identification and discrimination with complex movement sounds, *Journal of Cognitive Psychology*, 26:2, 157-165, DOI: [10.1080/20445911.2013.869226](https://doi.org/10.1080/20445911.2013.869226)

To link to this article: <http://dx.doi.org/10.1080/20445911.2013.869226>

PLEASE SCROLL DOWN FOR ARTICLE

Taylor & Francis makes every effort to ensure the accuracy of all the information (the "Content") contained in the publications on our platform. However, Taylor & Francis, our agents, and our licensors make no representations or warranties whatsoever as to the accuracy, completeness, or suitability for any purpose of the Content. Any opinions and views expressed in this publication are the opinions and views of the authors, and are not the views of or endorsed by Taylor & Francis. The accuracy of the Content should not be relied upon and should be independently verified with primary sources of information. Taylor and Francis shall not be liable for any losses, actions, claims, proceedings, demands, costs, expenses, damages, and other liabilities whatsoever or howsoever caused arising directly or indirectly in connection with, in relation to or arising out of the use of the Content.

This article may be used for research, teaching, and private study purposes. Any substantial or systematic reproduction, redistribution, reselling, loan, sub-licensing, systematic supply, or distribution in any form to anyone is expressly forbidden. Terms & Conditions of access and use can be found at <http://www.tandfonline.com/page/terms-and-conditions>

# Action perception via auditory information: Agent identification and discrimination with complex movement sounds

Christian Kennel<sup>1</sup>, Tanja Hohmann<sup>2</sup>, and Markus Raab<sup>1</sup>

<sup>1</sup>Institute of Psychology, German Sport University Cologne, Cologne, Germany

<sup>2</sup>Department of Sport and Exercise Science, University of Stuttgart, Stuttgart, Germany

Action and perception are represented in a common framework. Greater motor experience should therefore lead to improved perception. This has been shown with the help of visual stimuli. Given that rhythm and timing are important factors in movement perception, auditory self-recognition should also be superior to recognition of auditory stimuli produced by others. To test this hypothesis, we examined performance in a discrimination and an identification task with movement sounds produced by participants themselves (motor and auditory experiences), by the partner of the participant within the experimental study (auditory experience), and by strangers (no experience). The results of the discrimination task show that participants could distinguish between identical and different sound pairs independent of the agent. The results of the identification task show that participants could identify their own movement sounds significantly better than strangers' sounds. The coupling of action and perception thus seems detectable via naturally emerging movement sounds (auditory information). Taken together the present study confirms and extends current theories regarding action-perception coupling, by providing evidence that self–other effects occur in the auditory domain using movement sounds. Future research should explore the underlying (neurophysiological) mechanisms that account for the present results.

**Keywords:** Action; Agency; Movement; Perception; Sound.

Hearing is an essential sense for perceiving and acting upon information. In the sports context, many athletes have reported that they intentionally focus on sound in particular situations (e.g. when locating an opponent) to optimise their perception and subsequent movement. For example, very short movements (such as strokes in table tennis) or rhythmic movements (such as hurdling) produce characteristic sounds. Sometimes in situations such

as these, the auditory stimulus is not additional but rather the essential piece of information. We ask how athletes use auditory information to distinguish between different kinds of movements and if they are able to identify who produced the movement.

Action simulation approaches (Blakemore & Frith, 2005; Gallese & Goldman, 1998; Jeannerod, 2001) as well as the common coding theory (Hommel, Müsseler, Aschersleben, & Prinz, 2001;

---

Correspondence should be addressed to Christian Kennel, Institute of Psychology, German Sport University, Am Sportpark Müngersdorf 6, 50933 Cologne, Germany. E-mail: [c.kennel@dshs-koeln.de](mailto:c.kennel@dshs-koeln.de)

Current address: Markus Raab, Department of Applied Sciences, London South Bank University, London, UK.

We are grateful to Lukas Streese for help with data collection, Anita Todd for English Editing and the Performance Psychology Group of the German Sport University Cologne for their helpful comments.

This research was supported by the German Research Foundation [grant number DFG: RA940/13-1].

Prinz, 1997) are particularly useful for describing how the action system contributes to perception. They propose that a common mechanism maps perceived movements onto the perceiver's own motor system. The idea that perception and action interact bidirectionally has been supported by several investigations dealing with motor experience, motor intention, motor learning and motor competence (for an overview, see Schütz-Bosbach & Prinz, 2007). This research shows that humans are able to perceive movements by using their own motor system.

But how is the motor system involved in movement perception? Simulation theory (Gallese & Goldman, 1998) assumes that people predict actions by using motor experience. Wilson and Knoblich (2005) proposed that various brain areas translate a perceived movement into a motor program, which acts as an emulator (Grush, 2004). This emulator simulates the perceived movement internally. However, the motor system is not the only source providing information to enhance the quality of perception. When perceiving a movement (in the form of auditory, visual, sensorimotor or multi-sensory stimuli), people compare the present stimuli to representations stored in memory. These representations are available as forward models (Wolpert & Flanagan, 2001) that run offline (Schubotz, 2007). Thus, when a movement sound (or a video) is presented to a participant in a perceptual experiment, the participant compares the stimulus (delayed reafference) to predicted feedback (corollary discharge). The higher the match between predicted and actual feedback, the better is the perceptual performance. Additionally, the agent of a perceived stimulus can be identified by noting the sensory discrepancy between predicted and actual feedback (Blakemore, Wolpert, & Frith, 2000): A slight sensory discrepancy leads to an attribution of "self-generated." A high sensory discrepancy leads to an attribution of "caused by an external agent."

One way to investigate the influence of motor (or auditory) experience on perception is to evaluate the performance when own and other past movements are presented in perceptual experiments (Schütz-Bosbach & Prinz, 2007). The assumption behind this is that participants possess the best motor experience for own movements, but no motor experience with movements of friends and strangers (in our study auditory experience is existent for own- and partner-movement sounds). Therefore, in our experiment, we define motor, auditory or no experience as the

experiences generated by the available information during the previous recording session. The term *perceptual performance* is used equivalently to the success rate in the identification task.

Behavioural evidence for a connection of action and perception comes from studies in the visual domain. These studies show that a higher quality of action (expertise or experience) leads to better perception when watching own videos of darts (Knoblich & Flach, 2001), point-light displays of own basketball dribbling's (Hohmann, Troje, Olmos, & Munzert, 2011) or various own full-body movements (Loula, Prasad, Harber, & Shiffrar, 2005). Additionally, a recent line of research stressed the importance of action sounds. For instance, participants were able to recognise their own clapping sounds (Flach, Knoblich, & Prinz, 2004), even when only the temporal pattern of the original claps was presented by uniform tones. Another study indicated that pianists can better recognise and synchronise with their own recordings than those of others (Keller, Knoblich, & Repp, 2007). However, already basic human movement such as walking contains a lot of auditory information. Simple footstep sounds provide information (e.g. sex or mood) about the individual causing the sounds (Ekimov & Sabatier, 2006; Saarela & Hari, 2008). Furthermore, there are some studies that examine the perception of naturally occurring sounds in sport. Agostini, Righi, Galmonte, and Bruno (2004) showed that hammer throwers optimised their performance via training with auditory feedback. The sounds were generated by the movement of the hammer through the air. Another study found that golfers were able to discriminate sound recordings of their own movement from recordings of others' movements, except when the other person's sounds had nearly the same temporal factors (Murgia, Hohmann, Galmonte, Raab, & Agostini, 2012).

Besides behavioural evidence there is also neurophysiological evidence for a close connection between action and perception within the visual as well as the auditory domain using imaging techniques (Jeannerod, 2001; Rizzolatti, Fogassi, & Gallese, 2001). A functional magnetic resonance imaging (fMRI) study by Calvo-Merino, Glaser, Grèzes, Passingham, and Haggard (2005) showed a connection between motor expertise and the visual perception of actions. Dancers (ballet or capoeira) showed higher activation of the premotor cortex when the observed action corresponded to their own expertise. Another fMRI study examining the observation of table tennis strokes

revealed similar results. Participants assessed their own movement better than the movement of others, and higher activation of the premotor cortex was found (Bischoff et al., 2012). Bidet-Caulet, Voisin, Bertrand, and Fonlupt (2005) provided evidence that an area essential for the perception of biological motion (posterior superior temporal sulcus) is activated when participants just listen to a walking human. Furthermore, various neuroimaging studies show that both the perception of an action sound and the execution of the equivalent action activate similar brain areas (Kohler et al., 2002; see Aglioti & Pazzaglia, 2010, for a review). These brain areas contain representations which correspond to different components of the action. These components are the goals of action (Ticini, Schütz-Bosbach, Weiss, Casile, & Waszak, 2012), the context (context-related or context-free auditory object) and the type (living or man-made auditory objects) of action (De Lucia, Camen, Clarke, & Murray, 2009). Given the characteristics of complex (sports) movement (context-related, goal-orientated and man-made), the perceptual performance of action sounds from a hurdling task (which is used in this study) should be precise.

In summary, the coupling of action and perception is well established. Knowledge of this link originates mostly from visual, neurophysiological or fine motor skill studies. The existing studies conducted in the auditory modality examined movement sounds that could not be perceived by the individual under natural conditions. In contrast, we investigated sounds that are recorded naturally like we would perceive them. We refer to these sounds as auditory reafferences. Hearing is characterised by processing only sound waves generated from movement. In fact, the ear has been called the original movement detector (Effenberg & Mechling, 1999). One advantage of auditory perception over visual perception is its higher processing speed. In specific circumstances (cross-modal effects), auditory perception dominates visual perception (Shams, Kamitani, & Shimojo, 2000). Moreover, temporal structure and rhythm can be ideally depicted by auditory information (MacPherson, Collins, & Obhi, 2009). Another advantage is the lack of a perspective shift. Auditory information is perceived independently of the viewing direction in a complex movement situation (unlike visual information).

We extended previous work by examining a robust auditory connection between a complex movement situation and its naturally occurring perceived sound. Our hypotheses were that it is

possible to discriminate between movement sounds. Further, we hypothesise that a greater match between predicted feedback (corollary discharge) and actual feedback (reafference) would lead to better performance in movement recognition. Given the higher number of representations that people have with their own movements, individuals should be better at recognising their own sounds than those of partners (for whom they have created auditory representations) or strangers (for whom they have created no representations).

## METHOD

### Participants

Twenty-eight male students from the local university participated in return for financial compensation. They were aged between 20 and 33 years ( $M = 23.07$  years,  $SD = 3.08$ ). All had experience in hurdling (had passed a practical hurdling test with the same conditions as those of an athletics course at the university) and self-reported having no aural handicap. Body height ranged from 173 cm to 192 cm ( $M = 182.32$  cm,  $SD = 4.88$ ) and weight ranged from 68 kg to 90 kg ( $M = 77.04$  kg,  $SD = 6.06$ ). The lead leg (16 right legs, 12 left legs) had a length of 93.21 cm ( $SD = 2.45$ ) from trochanter major to the floor in a straight line. Anthropometric data were collected to match groups for the stimulus presentation. All participants fulfilled the criterion for inclusion in this study of being able to manage the hurdles in a four-step cycle.

### Apparatus

The movement sounds were recorded with Soundman OKM Classic II binaural in-ear microphones (sensitivity: 5 mV/Pa  $\pm$  3 dB). An A3 adapter (input impedance 1 kOhm; output impedance 47 kOhm) connected the microphones and the recording equipment (Soundman digital recorder DR2, 192 kpbs) to improve the recorded sound quality. The apparatus (digital recorder and amplifier) were placed on the right upper arm, fixed with adhesive tape. The participants also wore an acrylic windshield over the ears to shield the microphones against rustling when they were sprinting. Kinematic data were recorded at the third hurdle with a Casio EX-FH100 high-speed



**Figure 1.** The setting of the recording session.

camera with a recording speed of 120 frames/s. The experimental setting is shown in Figure 1.

## Stimulus generation

A pilot study with five athletes was conducted to determine the optimal surroundings, such as the location (inside or outdoors) and the distances between the height of the hurdles. Taking the pilot study findings into consideration, we collected the auditory and kinematic data on a synthetic-surface (Tartan) track in an athletic hall. The participants had to clear four hurdles in an overall distance of 38.50 m. The distance to the first hurdle was 13 m. The participants had to accomplish this part with eight steps. The distance between each of the four hurdles was 8.5 m. Participants had to take four steps between hurdles. These dimensions are equivalent to the International Association of Athletic Federations' (IAAF) official women's 100-m hurdles. The height of the hurdles was in accordance with the IAAF's official men's 400-m hurdles. The launch took place without a start signal (so as not to generate noise) from a starting block. The digital audio editor Audacity 1.2.6 was used to edit the recorded sounds. The beginning of every prepared stimulus was the first step after the

start out of the starting block. The end was the hurdle step (jump) before the last (fourth) hurdle. Overall there were 20 recorded steps. The duration of the stimulus ranged from 5.42 s to 7.81 s ( $SD = 0.26$ ). A 200-Hz sinus tone with a two-dimensional amplitude of 0.3 and duration of 2 s followed by 1 s of silence was inserted before the recorded sounds. The rationale for this was that participants would be better prepared when they were aware of the onset of the stimuli. We recorded five stimuli for every participant. We used one recording for a short training session of six trials and the remaining four in the subsequent perceptual experiment. Inquisit by Millisecond Software was used to present the stimuli.

## Procedure

For the recording sessions we invited two participants to the athletic hall. One ran the hurdles whereas the other listened blindfolded to his movement sounds (we instructed the two participants to be "partners" for the following experiment. Hereafter, we use the term *partner* defined as the respective partner within the experimental study). Then the situation was reversed. The aim of this procedure during the recording session was



to generate different experience levels for own-produced movement (motor and auditory experiences), partner-produced movement (auditory experience) and stranger-produced movement (no experience) sounds. After the recording session, we invited the participants to return individually one week later to participate in two laboratory experiments. The experiments were run consecutively, separated by a short break. The participants had to sit in front of a computer, follow the instructions presented on the screen and listen to the presented stimuli. In one experiment, participants performed a discrimination task. They were presented two movement sounds consecutively and had to decide whether the sounds were identical or different. In the other experiment, they performed an identification task in which they were asked whether the presented movement sound was their own, their partner's or a stranger's. The order of the two experiments was counterbalanced. The reaction time for each decision was measured in both experiments, but they were instructed that it was more important to answer correctly than to answer quickly. We measured both response quality and response time. In addition, we asked participants to rate their certainty (from 0, *unsure*, to 9, *sure*) after each answer. In both experiments, participants were not informed about the base rates of the different agencies. No feedback was provided during the experiments. The overall duration for both perceptual experiments was about one hour.

**Discrimination Task.** Accuracy in the (two-alternative forced-choice) discrimination task was based on 72 trials. Participants were presented 36 identical and 36 different pairs of sounds in random order. The identical sound pairs were either their own, their partner's or a stranger's, with 12 of each type. Each of these 12 pairs consisted of the four different recorded sounds, repeated three times. The different sound pairs were composed of the three possible combinations: own-partner, own-stranger and partner-stranger. We created four different stimulus sets for each combination, which were repeated three times, for a total of 12 presentations of each combination. We employed a within-subject design.

**Identification Task.** The participants performed 72 trials of the (three-alternative forced-choice) identification task. Trials consisted of 24 participants', 24 partners' and 24 strangers' sounds in random

order. We had recorded four sounds for the experiment which we each repeated six times.

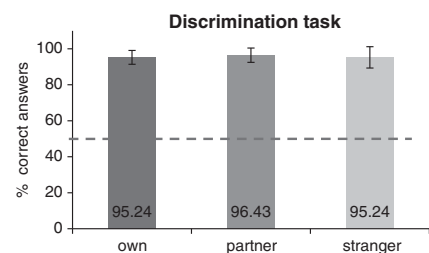
## Data analysis

To test our hypotheses, we performed two repeated-measures analysis of variance with pairwise Bonferroni correction, one for the discrimination task and one for the identification task. To consider a possible influence of reaction time or response certainty we performed four repeated-measures analysis of variance, two for the discrimination task and two for the identification task. To compare the performance in the identification task with chance level, we conducted a one-sample *t*-test for participant's own, partner's and stranger's sounds. Statistical significance was set at  $p < .05$  for all statistical tests.

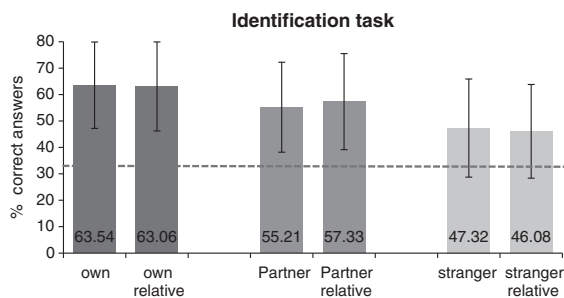
## RESULTS

The first research question was to examine if the participants could discriminate between identical and different movement sounds. This is a two-alternative forced-choice task. Chance performance was at 50%. Results show that this task was easy to handle (see Figure 2). Participants showed a discrimination rate of more than 95% ( $SD_{\text{own}} = 3.8$ ,  $SD_{\text{partner}} = 4.0$ ,  $SD_{\text{stranger}} = 5.9$ ). There was no significant difference between any of the conditions,  $F(2, 54) = .21$ ,  $p = .813$ ,  $\eta^2 = .01$ . Results are highlighted in Figure 2.

The second research question was to investigate if the participants were able to distinguish between their own, their partner's and a stranger's movement sounds. It was a three-alternative forced-choice task, so chance performance was at 33.3%. Figure 3 shows the results of the identification task.



**Figure 2.** Discrimination of identical and different sounds in the three conditions: own, partner and stranger. Error bars indicate standard deviation. The broken line represents chance level (50%).



**Figure 3.** Identification of own, partner's, and stranger's movement sounds from a hurdling task. The figure highlights the percentage of correct decisions (absolute and relative to response bias). Error bars indicate standard deviation. The broken line represents chance level (33%).

The agent identification rate was highest for participants' own sounds with 63.5% ( $SD = 32.7$ ). Partners' sounds were detected with 55.2% ( $SD = 34.0$ ) and strangers' sounds with 47.3% ( $SD = 37.1$ ) accuracy. Performance in all situations was significantly above chance,  $t(27) = 10.2, 8.5, 6.7, p \leq .001$ .

A repeated-measures analysis of variance revealed a significant difference in the identification performance depending on the agent,  $F(2, 54) = 3.23, p = .047, \eta^2 = .11$ . A pair-wise comparison with Bonferroni correction indicated a significant difference between own and strangers' sounds ( $p = .016$ ). Between own and partners' sounds ( $p = .769$ ) and partners' and strangers' sounds ( $p = .696$ ) there was no significant difference. Compared to the findings of other studies (Beardsworth & Buckner, 1981), our results show no noteworthy response bias (own = 34.3%, partner = 32.6%, stranger = 33.1%). The relative identification of their own sounds was highest with 63.06% ( $SD = 33.7$ ). Partners' sounds were identified in 57.33% ( $SD = 36.3$ ) of the cases and strangers' sounds in 46.08% ( $SD = 35.5$ ).

To consider a possible influence of the response certainty and the response time we analysed the results in both tasks. A repeated-measures analysis of variance revealed no significant difference for the certainty ratings in the discrimination task,  $F(2, 54) = .49, p = .613, \eta^2 = .02$ ; the certainty ratings in the identification task,  $F(2, 54) = .04, p = .959, \eta^2 < .01$ ; the response times in the discrimination task,  $F(2, 54) = 1.39, p = .258, \eta^2 = .05$  and the response times in the identification task,  $F(2, 54) = .43, p = .651, \eta^2 = .02$ .

## DISCUSSION

The aim of the present study was to investigate the coupling of action and perception based on

auditory information from a complex movement situation. We assumed that motor and perceptual representations, stored in memory, enhance performance in an offline perceptual task (Jeannerod, 2001). The results from the discrimination task show that it is possible to distinguish between different auditory stimuli. Success rates for the discrimination task were very high for own, partners' and strangers' sounds but independent of the agent. The high accuracy of this discrimination task can be traced back to the rich informational content of the recorded stimulus material and a variation within the different stimuli of one participant. Results from the identification task show that participants were able to identify agents by using only auditory information. The accuracy of this agent identification was dependent on motor and perceptual experiences. In more detail, with an increasing number of present representations matching the stimuli (motor and auditory), the perceptual performance was better. Concerning the reaction times and certainty there was a difference neither in the discrimination nor in the identification task.

In line with our hypotheses, people appear to be sensitive to auditory information (Schaffert, Mattes, & Effenberg, 2011). Several studies (Keller et al., 2007; Knoblich & Repp, 2009; Repp & Keller, 2010; Repp & Knoblich, 2004) have shown that auditory stimuli, such as piano playing or tapping sounds, contain information that enables people to perceive agency. Moreover, naturally occurring movement sounds also include information useful for discrimination and identification. Thus, our general findings support the existence of self-other differences in another domain—adding to the results from visual studies (Loula et al., 2005) and imaging procedures (Calvo-Merino et al., 2005). Our results show that movement with a rhythmic character can be identified even better (with a higher accuracy) through auditory information. Movement sounds might represent the essential information for perception of complex movement. Loula et al. (2005) reported that walking and running identification was not above chance level. They found that only more expressive actions such as dancing or boxing could be reliably identified. In our experiment, we determined that even small rhythmic differences in hurdling can be detected at well above chance level.

This study is the first to examine naturally occurring movement sounds, by recording them similar to live perceived sound in a sports context.

A recent study has postulated that visual, multi-sensory and solely auditory movement perception might use similar cognitive mechanisms (Justen, Herbert, Werner, & Raab, 2013). Together with the present study, this furthers the understanding of the relationship between motor experience and action-perception from a functional different sense.

Yet, perception in a complex sports situation never relies on only one sense. For instance, other studies have analyzed the relation between the auditory and visual senses (Thomas & Shiffrar, 2010; Sevdalis & Keller, 2010). This was examined by presenting point-light displays with added auditory information. Based on our results, it is not possible to specify the relation between auditory, visual and motor experiences in perception. The results highlighted in Figure 3 show that both motor and auditory experiences led to an increased perceptual performance above chance level. Motor experience (exclusively for own movement) seems to have been slightly more important than auditory experience (own and partner). This is in line with findings from the visual domain (Hohmann et al., 2011), proposing the motor experience to be the determining factor (compared to visual experience). But given that there was no significant difference in perceptual performance between own and partner's sounds, and no situation with exclusive motor experience, this should be examined in more detail in future research.

On the basis of the bidirectional connection between auditory perception and action execution and the great sensitivity to auditory information, the results of this study suggest that auditory information can influence movement. This raises the possibility of integrating the perception of movement sounds into athletes' training. Other studies have already shown a positive influence on performance when training with auditory feedback (Agostini et al., 2004). Hurdling is a movement, generating a complex sound in which the characteristics of the footstep and the step rhythm seem to deliver salient information as reported from the participants in the post-experiment questionnaire. However, single components like waveform, phase, amplitude, frequency and pitch can be separated. In future studies it may be worth examining which components of the sound are used for identification or discrimination. More precisely, it should be determined if the quality of perception depends on singular sound characteristics. Another perspective would be the neuroscientific investigation of complex human movement sounds, which are recorded in a way

which is congruent with the auditory perception during the actual movement. It would be interesting to explore if these human action sounds lead to previously found activation in the action observation network (Cross, Kraemer, Hamilton, Kelley, & Grafton, 2009). This future research line would promote our understanding of action-perception coupling on the basis of commonplace real-life situations.

The present study also had some limitations. We recorded the sounds in a closed track-and-field hall to avoid disturbance from wind, but occasionally there was background or breathing noise on the recordings. All participants wore the same type of running shoes, but not the exact model. Some participants reported that they chose the wrong agent at the beginning of the identification task but stuck by this decision until the end. A post-experiment questionnaire pointed out that these limitations most likely had no influence on the results. The open question (What did you focus on specifically?) with the possibility of multiple responses revealed that the participants made their decisions mainly based on step sounds (71.4%), step rhythm (58.3%), loudness (33.3%) or breathing noise (16.7%).

In conclusion, it has been found that motor and auditory experiences have an influence on the perception of movement. This was investigated for the first time in a complex real-life sports situation with natural sounds produced from participants' own movements.

Original manuscript received March 2013

Revised manuscript received November 2013

Revised manuscript accepted November 2013

First published online December 2013

## REFERENCES

- Aglioti, S. M., & Pazzaglia, M. (2010). Representing actions through their sound. *Experimental Brain Research*, 206, 141–151. doi:10.1007/s00221-010-2344-x
- Agostini, T., Righi, G., Galmonte, A., & Bruno, P. (2004). The relevance of auditory information in optimizing hammer throwers performance. In P. B. Pascolo (Ed.), *Biomechanics and sports* (pp. 67–74). Vienna: Springer.
- Beardsworth, T., & Buckner, T. (1981). The ability to recognize oneself from a video recording of one's movements without seeing one's body. *Bulletin of the Psychonomic Society*, 18, 19–22. doi:10.3758/BF03335558
- Bidet-Caulet, A., Voisin, J., Bertrand, O., & Fonlupt, P. (2005). Listening to a walking human activates the



- temporal biological motion area. *Neuroimage*, 28, 132–139. doi:[10.1016/j.neuroimage.2005.06.018](https://doi.org/10.1016/j.neuroimage.2005.06.018)
- Bischoff, M., Zentgraf, K., Lorey, B., Pilgramm, S., Balser, N., Baumgartner, E., ... Munzert, J. (2012). Motor familiarity: Brain activation when watching kinematic displays of one's own movements. *Neuropsychologia*, 50, 2085–2092. doi:[10.1016/j.neuropsychologia.2012.05.009](https://doi.org/10.1016/j.neuropsychologia.2012.05.009)
- Blakemore, S.-J., & Frith, C. (2005). The role of motor contagion in the prediction of action. *Neuropsychologia*, 43, 260–267. doi:[10.1016/j.neuropsychologia.2004.11.012](https://doi.org/10.1016/j.neuropsychologia.2004.11.012)
- Blakemore, S.-J., Wolpert, D., & Frith, C. (2000). Why can't you tickle yourself? *Neuroreport*, 11, R11–R16. doi:[10.1097/00001756-200008030-00002](https://doi.org/10.1097/00001756-200008030-00002)
- Calvo-Merino, B., Glaser, D. E., Grèzes, J., Passingham, R. E., & Haggard, P. (2005). Action observation and acquired motor skills: An fMRI study with expert dancers. *Cerebral Cortex*, 15, 1243–1249. doi:[10.1093/cercor/bhi007](https://doi.org/10.1093/cercor/bhi007)
- Cross, E. S., Kraemer, D. J., Hamilton, A. F. D. C., Kelley, W. M., & Grafton, S. T. (2009). Sensitivity of the action observation network to physical and observational learning. *Cerebral Cortex*, 19, 315–326. doi:[10.1093/cercor/bhn083](https://doi.org/10.1093/cercor/bhn083)
- De Lucia, M., Camen, C., Clarke, S., & Murray, M. M. (2009). The role of actions in auditory object discrimination. *Neuroimage*, 48, 475–485. doi:[10.1016/j.neuroimage.2009.06.041](https://doi.org/10.1016/j.neuroimage.2009.06.041)
- Effenberg, A. O., & Mechling, H. (1999). The contribution of motor-acoustic information to motor learning. In P. Parisi, F. Pigozzi, & G. Prinzi (Eds.), *Sport science'99 in Europe. Proceedings of the 4th Annual Congress of the ECSS* (p. 780). Rome: University of Motor Science.
- Ekimov, A., & Sabatier, J. M. (2006). Vibration and sound signatures of human footsteps in buildings. *The Journal of the Acoustical Society of America*, 120, 762. doi:[10.1121/1.2217371](https://doi.org/10.1121/1.2217371)
- Flach, R., Knoblich, G., & Prinz, W. (2004). Recognizing one's own clapping: The role of temporal cues. *Psychological Research*, 69, 147–156. doi:[10.1007/s00426-003-0165-2](https://doi.org/10.1007/s00426-003-0165-2)
- Gallese, V., & Goldman, A. (1998). Mirror neurons and the simulation theory of mind-reading. *Trends in Cognitive Sciences*, 2, 493–501. doi:[10.1016/S1364-6613\(98\)01262-5](https://doi.org/10.1016/S1364-6613(98)01262-5)
- Grush, R. (2004). The emulation theory of representation: Motor control, imagery, and perception. *Behavioral and Brain Sciences*, 27, 377–442.
- Hohmann T., Troje, N. F., Olmos, A., & Munzert, J. (2011). The influence of motor expertise and motor experience on action and actor recognition. *Journal of Cognitive Psychology*, 23, 403–415. doi:[10.1080/20445911.2011.525504](https://doi.org/10.1080/20445911.2011.525504)
- Hommel, B., Müsseler, J., Aschersleben, G., & Prinz, W. (2001). The theory of event coding (TEC). A framework for perception and action planning. *Behavioral and Brain Sciences*, 24, 849–878. doi:[10.1017/S0140525X01000103](https://doi.org/10.1017/S0140525X01000103)
- Jeannerod, M. (2001). Neural simulation of action: A unifying mechanism for motor cognition. *Neuroimage*, 14, S103–S109. doi:[10.1006/nimg.2001.0832](https://doi.org/10.1006/nimg.2001.0832)
- Justen, C., Herbert, C., Werner, K., & Raab, M. (2013). Self vs. other: Neural correlates underlying agent identification based on unimodal auditory information as revealed by electrotopomography (sLORETA). *Neuroscience*. Advance online publication. doi:[10.1016/j.neuroscience.2013.11.042](https://doi.org/10.1016/j.neuroscience.2013.11.042)
- Keller, P. E., Knoblich, G., & Repp B. H. (2007). Pianists duet better when they play with themselves: On the possible role of action simulation in synchronization. *Consciousness and Cognition*, 16, 102–111. doi:[10.1016/j.concog.2005.12.004](https://doi.org/10.1016/j.concog.2005.12.004)
- Knoblich, G., & Flach, R. (2001). Predicting the effects of actions: Interactions of perception and action. *Psychological Science*, 12, 467–472. doi:[10.1111/1467-9280.00387](https://doi.org/10.1111/1467-9280.00387)
- Knoblich, G., & Repp, B. H. (2009). Inferring agency from sound. *Cognition*, 111, 248–262. doi:[10.1016/j.cognition.2009.02.007](https://doi.org/10.1016/j.cognition.2009.02.007)
- Kohler, E., Keysers, C., Umiltà, M. A., Fogassi, L., Gallese, V., & Rizzolatti, G. (2002). Hearing sounds, understanding actions: Action representation in mirror neurons. *Science*, 297, 846–848. doi:[10.1126/science.1070311](https://doi.org/10.1126/science.1070311)
- Loula, F., Prasad, S., Harber, K., & Shiffrar, M. (2005). Recognizing people from their movement. *Journal of Experimental Psychology: Human Perception and Performance*, 31, 210–220. doi:[10.1037/0096-1523.31.1.210](https://doi.org/10.1037/0096-1523.31.1.210)
- MacPherson, A. C., Collins, D., & Obhi, S. S. (2009). The importance of temporal structure and rhythm for the optimum performance of motor skills: A new focus for practitioners of sport psychology. *Journal of Applied Sport Psychology*, 21, S48–S61. doi:[10.1080/10413200802595930](https://doi.org/10.1080/10413200802595930)
- Murgia, M., Hohmann, T., Galmonte, A., Raab, M., & Agostini, T. (2012). Recognising one's own motor actions through sound: The role of temporal factors. *Perception*, 41, 976–987. doi:[10.1068/p7227](https://doi.org/10.1068/p7227)
- Prinz, W. (1997). Perception and action planning. *European Journal of Cognitive Psychology*, 9, 129–154. doi:[10.1080/713752551](https://doi.org/10.1080/713752551)
- Repp, B. H., & Keller, P. E. (2010). Self versus other in piano performance: Detectability of timing perturbation depends on personal playing style. *Experimental Brain Research*, 202, 101–110. doi:[10.1007/s00221-009-2115-8](https://doi.org/10.1007/s00221-009-2115-8)
- Repp, B. H., & Knoblich, G. (2004). Perceiving action identity: How pianists recognize their own performances. *Psychological Science*, 15, 604–609. doi:[10.1111/j.0956-7976.2004.00727.x](https://doi.org/10.1111/j.0956-7976.2004.00727.x)
- Rizzolatti, G., Fogassi, L., & Gallese, V. (2001). Neurophysiological mechanisms underlying imitation and the understanding of action. *Nature Reviews Neuroscience*, 2, 661–670. doi:[10.1038/35090060](https://doi.org/10.1038/35090060)
- Saarela, M. V., & Hari, R. (2008). Listening to humans walking together activates the social brain circuitry. *Social Neuroscience*, 3, 401–409. doi:[10.1080/17470910801897633](https://doi.org/10.1080/17470910801897633)
- Schaffert, N., Mattes, K., & Effenberg, A. O. (2011). An investigation of online acoustic information for elite rowers in on-water training conditions. *Journal of Human Sport & Exercise*, 6, 392–405. doi:[10.4100/jhse.2011.62.20](https://doi.org/10.4100/jhse.2011.62.20)

- Schubotz, R. I. (2007). Prediction of external events with our motor system: Towards a new framework. *Trends in Cognitive Sciences*, 11, 211–218. doi:[10.1016/j.tics.2007.02.006](https://doi.org/10.1016/j.tics.2007.02.006)
- Schütz-Bosbach, S., & Prinz, W. (2007). Perceptual resonance: Action-induced modulation of perception. *Trends in Cognitive Sciences*, 11, 349–355. doi:[10.1016/j.tics.2007.06.005](https://doi.org/10.1016/j.tics.2007.06.005)
- Sevdalis, V., & Keller, P. E. (2010). Cues for recognition in point-light displays of action performed in synchrony with music. *Consciousness and Cognition*, 19, 617–626. doi:[10.1016/j.concog.2010.03.017](https://doi.org/10.1016/j.concog.2010.03.017)
- Shams, L., Kamitani, Y., & Shimojo, S. (2000). What you see is what you hear. *Nature*, 408, 788–788. doi:[10.1038/35048669](https://doi.org/10.1038/35048669)
- Ticini, L. F., Schütz-Bosbach, S., Weiss, C., Casile, A., & Waszak, F. (2012). When sounds become actions: Higher-order representation of newly learned action sounds in the human motor system. *Journal of Cognitive Neuroscience*, 24, 464–474. doi:[10.1162/jocn\\_a\\_00134](https://doi.org/10.1162/jocn_a_00134)
- Thomas, J. P., & Shiffrar, M. (2010). I can see you better if I can hear you coming: Action-consistent sounds facilitate the visual detection of human gait. *Journal of Vision*, 10, 1–11.
- Wilson, M., & Knoblich, G. (2005). The case of motor involvement in perceiving conspecifics. *Psychological Bulletin*, 131, 460–473. doi:[10.1037/0033-2909.131.3.460](https://doi.org/10.1037/0033-2909.131.3.460)
- Wolpert, D. M., & Flanagan, J. R. (2001). Motor prediction. *Current Biology*, 11, 729–732. doi:[10.1016/S0960-9822\(01\)00432-8](https://doi.org/10.1016/S0960-9822(01)00432-8)