Movement Expertise Influences Gender Recognition in Point-Light Displays of Musical Gestures

Clemens Wöllner,[*1] Frederik J.A. Deconinck,[#2]

[*]Institute of Musicology and Music Education, University of Bremen, Germany
[#]Institute for Biomedical Research into Human Movement and Health, Manchester Metropolitan University, UK
[1]woellner@uni-bremen.de, [2]F.Deconninck@mmu.ac.uk

ABSTRACT

We investigated (a) whether observers perceive the gender of orchestral conductors in point-light displays across multimodal conditions and (b) whether there are quantifiable motion differences between male and female conductors. We hypothesised that in explicitly trained conducting gestures, gender differences are less pronounced as compared to walking motion. Gestures of male and female orchestral conductors were recorded with a motion capture system while they conducted two excerpts from a Mendelssohn string symphony to musicians. Point-light displays were created according to the following conditions: static image (no movement), gait, visual-only and audiovisual conducting. In addition, auditory-only versions of the same music were produced. Musically trained observers distinguished best between male and female conductors in gait and static images, for which differences in body morphology and/or motion parameters were found in accordance with previous research. For conducting movements, no significant motion differences were recorded. Accuracy of gender recognition was influenced by conductors' expertise: While observers perceived the gender of less experienced conductors' above chance level for visual-only and audiovisual point-light displays of conducting, displays of experienced conductors permitted correct recognition for gait and static images only, but not for the three conducting conditions. Results point to a response bias in judgments such that experienced conductors were more often judged to be male. We conclude that judgement accuracy depended both on conductors' level of expertise as well as on observers' concepts, suggesting that perceivable differences between men and women diminished for highly trained movements of experienced individuals.

I. INTRODUCTION

Gender recognition has been studied for common daily movements such as walking and running. Relatively little is known about the availability of gender cues in deliberately trained and more technical movement skills. In this study, we hypothesise that in skilled movements, global gender differences diminish due to extensive training. We investigate the accuracy of gender recognition for point-light displays of movements performed with different levels of expertise. In particular, observers' ability to recognise the gender of experienced and less experienced orchestral conductors – a professional domain with a large gender imbalance – was analysed.

Point-light displays present a seemingly random constellation of dots, which observers recognise as being derived from human or animal motion as soon as this constellation begins to move. It has been shown that people are able to recognise the gender and features such as emotional affect of these point-light displays, indicating the capacity of the human visual system to mediate and utilise cues that provide hints of these specific features (for a review, see Pollick, Kay, Heim & Stringer, 2005). The ability to recognise gender in point light-displays evidently implies the existence of different cues characterizing male and female individuals. Both differences in body morphology and differences in motion may serve as gender-specific cues (Pollick et al., 2005; Pollick, Paterson, Bruderlin & Sanford, 2001). Although differences in biological motion and morphology have been identified and quantified, it remains challenging to determine what information observers actually use to infer gender from point-light displays. Taking gait as a thoroughly-studied example, two theoretical models have been proposed to explain individuals' ability to distinguish between displays of males and females. A first model postulates that gender recognition is mainly based on differences in structure (i.e. body morphology), in particular the ratio of the shoulder width to the sum of the hip and shoulder widths ("centre of moment"; Cutting, Proffitt, & Kozlowski, 1978). Anthropometric evidence indicates that shoulder width is greater in men than in women (e.g. Heinz, Peterson, Johnson, & Kirk, 2003). Second, the model from Mather and Murdoch (1994) postulates motion differences for gender recognition. In this regard, the lateral body sway of male and female walkers is distinctly different, with increased medio-lateral movement of the hip in women and greater head and shoulder translation in men (Mather & Murdoch, 1994). In a research review of gender recognition in walking, Pollick et al. (2005) report average proportions correct of 66% for side views, and 71% for other viewpoints (frontal and oblique). Nevertheless, gender recognition is possible above chance even for static frontal point-light images (Davis & Gao, 2004), leading to the conclusion that observers rely predominantly on structural differences.

In a study using point-light displays of arm movements such as knocking or waving, Pollick, Lestou, Ryu and Cho (2002) asked observers to identify gender and affect (angry vs. neutral) of these movements. Human recognition accuracy was compared to an automatic "ideal observer" based on a pattern classification algorithm using 2D motion information. While human observers were able to indicate the intended affect above chance level, gender was not reliably recognised in the arm movements. The algorithm, on the other hand, achieved high sensitivity in gender recognition. The extent to which observers are able to use gender-specific information appears to be task dependent.

A pertinent question that has not been addressed in previous research is whether technical expertise or expert motor skill may affect gender-specific cues in point-light displays. The amount of deliberate and extensive training required by performing arts such as dancing, playing a musical instrument or conducting ultimately leads to high degrees of technical perfection. The outcome of such extensive motor training has been studied across several fields (for an overview, see Magill, 2004), indicating that expert motor performance is characterised by accuracy, precision, consistency and persistence. In a study of violin playing – evidently among the domains requiring very high motor skill – Konczak, van der Velden and Jaeger (2009) found that for particular movements, expert violinists possessed higher degrees of motor consistency and precision compared to novices. Moreover, experts reach high levels of adaptability (Gentile, 2000) and generalisability of their motor skill over situational or personal invariants (Magill, 2004), suggesting that motor performance becomes more stable and independent from external or individual-related factors. As a consequence, the kinematics and kinetics of expert performance are defined more by the laws of mechanics and motor control specifying the goal of the task, and less by individual motion characteristics that are still observable in less trained individuals. Accordingly, one could argue that experts' motor performance is also more independent from gender factors, especially for tasks that do not differentiate per se between a performer's gender (as opposed, for instance, to gender-specific dance movements, see Calvo-Merino, Grèzes, Glaser, Passingham, & Haggard, 2006). Point-light displays of expert motor performance should thus afford fewer or no gender-specific cues compared to novice displays.

Therefore we also ask in the current study, whether motion invariants permitting the recognition of gender in point-light displays of male and female orchestral conductors are more controlled in experienced individuals as compared to less experienced individuals. Among various musical professions, conducting appears to be one of the last fields principally dominated by males, and only recently more female conductors have been taking over responsibilities in orchestras (Edwards, 2003). Experimental research on musical conducting has concentrated on beat perception in point-light displays (Luck & Sloboda, 2009; Wöllner, Deconinck, Parkinson, Hove & Keller, 2012) and expressive features of conductors' gestures in relation to motion quantity (e.g., Wöllner & Auhagen, 2008). Typically only a limited number of conductors were studied, and to this end, gender-specific characteristics were not scrutinised in empirical research. Therefore it is not known whether movements of male and female orchestral conductors differ.

Hypotheses

Based on research into structural and motion differences between male and female walkers, we investigated whether observers perceive the gender in point-light displays of a deliberately trained motor skill. We first hypothesised that recognition accuracy depends on type of movement. Observers were expected to judge the conductors' gender reliably for walking as in previous studies, but less so for skilled orchestral conducting gestures because of the higher generalisability of trained motor skills over individual-related invariants. Second, we investigated whether conductors' motion expertise had an impact on observers' judgment accuracy. Due to extensive training and enhanced motor skills, more experienced conductors should afford fewer motion cues of their gender compared to less experienced conductors.

II. METHODS

A. Participants

Point-light displays of the movements of ten orchestral conductors were employed in the current study (for examples, see Figure 1). Five of them were female (mean age: 34.60 years, *SD* = 10.31), and five were male (mean age: 31.40 years, *SD* = 10.11). Based on their professional performance experience in public concerts, conductors were assigned to two groups of expertise (novices and experts). Male and female conductors were matched according to range of experience and age prior to the experiment, and no significant group differences occurred between them in age, experience or other relevant variables.

Twenty-four musically trained observers were presented with point-light displays of the conductors. Their mean age was 23.13 years (*SD* = 3.04), 15 were female. At the time when the study was carried out, training on musical instruments averaged 12.13 years (*SD* = 4.74), and each observer performed about 13 times per year under the direction of a conductor. According to the local institution's ethic guidelines, observers and conductors provided their informed consent prior to taking part, all received remuneration.

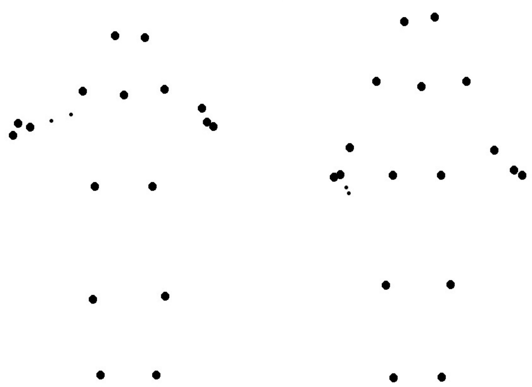

Figure 1. Point-light displays of a female conductor (left) and a male conductor (right).

B. Stimulus Material

Conductors were recorded with a ten camera motion capture system (Vicon, Oxford, UK; temporal resolution: 200 Hz). The 3D-position of 35 markers (full-body marker set) plus two markers for the baton was captured while they conducted the beginning of Mendelssohn's String Symphony No. 9 in C minor. Five advanced student string musicians of a major conservatoire, one for each voice of the musical scores (two violins, two violas, one cello), performed the music according to the individual conductors' intentions conveyed via their gestures. Before recording took place, each conductor briefly rehearsed the piece with the musicians. The sound recording was synchronised with the motion capture system via a DV camera connected to Vicon.

Point-light displays were created with customised MATLAB routines (Mathworks Inc., Psychophysics Toolbox version 3; Brainard, 1996; Pelli, 1996). Out of the full body model, 17 markers were selected and presented as black dots on a white screen as follows: one marker for each ankle (lateral malleolus of tibia), knee (lateral epicondyle of femur), hip (anterior superior iliac spine), shoulder (posterior acromion of clavicle), elbow (lateral epicondyle of humerus), wrist (styloid process of the ulna) and tip of the index finger, two for the front head (left and right facet of frontal bone), one for the top of the sternum, and two dots for the baton, which were smaller in size in order to distinguish them from the body markers (Figure 1).

Two short musical excerpts were chosen from the whole piece of music: a) the beginning of the *grave* section (1.5 measures, total duration 7.080-11.400 ms, depending on each conductor's interpretation), and b) the start of the *allegro* section (4.5 measures, 6.040-9.320 ms). Excerpt duration was not significantly different regarding conductors' gender or expertise (independent samples t-tests on number of frames). In addition, conductors' gait was recorded while they were walking normally, and frontal point-light displays containing the 15 anatomical markers (no baton) of one complete stride cycle (two consecutive steps) were created. Finally, a static frontal point-light image was extracted from the beginning of the gait cycle showing conductors standing with both arms downwards.

C. Design and Procedure

The experiment was undertaken as a within-participants (repeated measures) design. Observers watched point-light displays of all ten conductors under the following conditions: visual-only (two excerpts from the Mendelssohn string symphony without sound), full gait cycle, auditory-only (same music as in the visual-only condition for each conductor), static images, audiovisual (point-light displays including sound). The total number of trials was 120. Using binary forced-choice judgments, observers indicated whether the motion was derived from a male or female person. In the auditory-only condition, observers indicated whether they believed that the music was interpreted by a male or female conductor. If observers were unsure, they were still asked to provide an answer.

III. RESULTS

A. Overall Gender Judgments

We first analysed whether there are differences according to condition (type of motion, display modus). D-prime scores, taking into account potential response biases, were calculated and tested in one-sample t-tests against chance level. Chance level in d-prime analysis is defined as similar numbers of correct ("male judged as male") and erroneous ("female judged as male") responses, leading to a difference value of zero. Analyses for all conductors showed that d-prime scores for gait (M = 1.09, SEM = 0.18) and static images (M = 0.75, SEM = 0.11) were significantly different from zero, $t(23) = 6.13$, $p < .001$, and $t(23) = 6.57$, $p < .001$, respectively. In addition, audiovisual presentations were recognised above chance (M = 0.36, SEM = 0.12; $p < .01$), $t(23) = 3.04$, $p < .01$. Gender was not perceived in visual-only and auditory-only conditions ($p > .26$).

Results were not influenced by observers' gender as shown in independent samples t-tests on d-prime scores. Thus male observers did not judge a higher proportion of conductors to be male, and vice versa.

A repeated-measures ANOVA resulted in a main effect for Condition, $F(4, 92) = 11.78$, $p < .001$, $\eta^2 = .339$. Post-hoc comparisons (Bonferroni) indicate that gender was recognised best in gait (compared to visual-only: $p < .001$, to auditory-only $p < .01$, compared to audiovisual $p < .05$), followed by static images (compared to visual-only: $p = .001$, and to auditory-only: $p < .05$). Differences between audiovisual and other conducting conditions were not statistically significant in post-hoc comparisons.

B. Influence of Conductors' Expertise on Judgements

The second hypothesis addressed if conductors' motor experience had an impact on whether or not observers perceived gender-specific characteristics. In separate one-sample t-tests for each group of expert and novice conductors, recognition d-prime scores differed significantly from chance level for gait and static images (all $p \leq .001$), both in experts and novices (Figure 2). In the three conducting conditions (visual-only, auditory-only, audiovisual), observers did not perceive the gender of expert conductors. For novice conductors, on the other hand, gender recognition was above chance level for visual-only and audiovisual conditions, $t(23) = 3.10$, $p < .01$, and $t(23) = 4.02$, $p = .001$, respectively. Thus, while motion and morphological cues in walking or static images facilitated gender recognition in point-light displays of all conductors, observers perceived the gender only in novice conductors' movements, but not in the highly trained gestures of expert conductors.

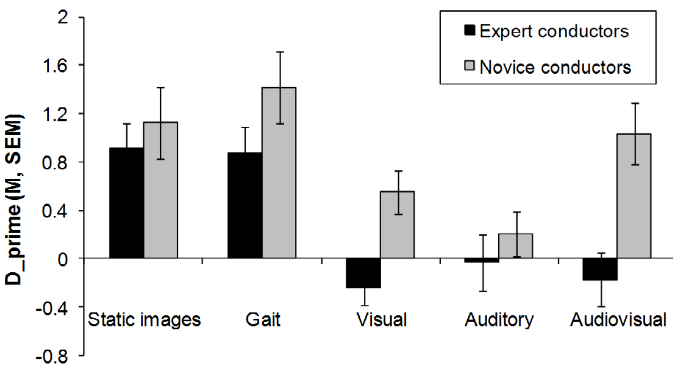

Figure 2. Mean D-prime scores for novice and expert conductors.

In order to further analyze this effect, it was tested whether "false alarms" rates were higher for expert conductors, meaning that experienced conductors were predominantly perceived to be male when in fact the motion was from female conductors. For the visual-only condition, the mean false alarm rate for expert conductors was .67 (SEM = 0.03) and for novice conductors .47 (SEM = 0.04). A dependent-samples t-tests showed that this difference was significant, $t(23) = 4.13$, $p < .001$. Similarly for the audiovisual condition, the mean false alarm rate for experienced conductors was .65 (SEM = 0.05) and for novice conductors .47 (SEM = 0.05), $t(23) = 2.49$, $p < .05$. No significant differences occurred in false alarm rates for other conditions. This result indicates that experienced conductors were more often judged to be male even when they were actually female.

C. Morphological Structure and Motion Differences

Finally, potential differences in body morphology and motion were analysed with regard to gender and expertise groups of conductors. Mann-Whitney U tests indicated that men had indeed a greater shoulder width ($U = 1.00$, $Z = -2.40$, $p < .05$) and were taller ($U = 0.00$, $Z = -2.61$ $p < .01$) than women. For both shoulder/hip ratio ($U = 4.00$, $Z = -1.78$, $p = .095$) and estimated Q angle ($U = 21.00$, $Z = 1.78$, $p = .095$) a trend towards significance was found, with tendencies for shoulder/hip ratio to be larger and Q angle to be smaller in men compared to women. There were no differences between expert and novice conductors for structural parameters.

For the gait motion parameters, male and female conductors differed significantly in terms of step length ($U = 2.00$, $Z = 4.787$, $p < .05$), cadence ($U = 23.00$, $Z = 2.20$, $p < .05$) and pelvic tilt ($U = 25.00$, $Z = 2.61$, $p < .01$), whereas no gender difference was found for gait speed. Again, no difference was found between the distributions of experienced and less-experienced conductors for gait motion parameters.

Analysis of conducting motion parameters revealed relatively large inter-individual differences for total baton trajectory, shoulder sway, pelvic sway, and movement smoothness. Yet no significant between-group differences for male and female conductors were found. With regard to the two expertise groups, inspection of the vertical acceleration plots of the baton indicated a noisier signal in the less-experienced group, which was supported by a significantly higher number of peaks in acceleration plots (novices: 49.7; experts: 35.9; $U = 0.50$, $Z = -2.62$, $p < 0.01$). Further motion parameters were statistically similar across the two expertise groups.

Thus, while male and female conductors differed in body morphology, quantitative analyses of motion cues did not yield gender-specific effects. Between the two expertise groups, conversely, no morphological differences were obtained, yet expert conductors' motion differed from those of novice conductors in an important measure related to expertise.

IV. DISCUSSION

This study examined whether human observers are able to distinguish the performer's gender in a deliberately trained and technically complex skill. Point-light displays of conducting motion (presented to observers in multimodal conditions) were compared with static images and gait motion, for which previous research evidenced gender recognition above chance. While static images, gait, and conducting contain similar gender-specific *structural cues* related to body morphology (see Pollick et al., 2005), highly trained motor skills should be less dependent on person-related movement invariants (Magill, 2004) and, as a consequence, may afford fewer *motion cues* for gender recognition. Our findings show that independent observers distinguished best between point-light displays of male and female individuals in gait and static images. Gender was not reliably detected in visual presentations of orchestral conducting gestures. Separate analyses revealed an effect of motor expertise such that the group of expert conductors did not afford cues for gender recognition in skilled movements, while the gender of novice conductors was recognised above chance level. Analyses of observers' response bias indicated that experienced conductors were more likely judged to be male. Explanations for these findings are discussed with regard to skill-related availability of motion cues and observer-related utilisation of motion cues for gender recognition, as well as constructs of gender biases in responses.

The ability to identify gender-specific features in point-light displays relies on the visual system's capacity to perceive and interpret differences in morphological and movement-related characteristics (Johnson & Tassinary, 2005). While converting a normal image to a point-light display masks some of these attributes (e.g., face or secondary sex characteristics), a number of gender-specific cues remain available such as centre of moment (Cutting et al., 1978) or lateral body sway (Mather & Murdoch, 1994). Consistent with previous research, our data revealed differences between male and female individuals in morphological structure (height, shoulder width) and gait movements (cadence, pelvic tilt). These cues, potentially combined with further nearly significantly different features (e.g., Q angle), were utilised to achieve above-chance proportions correct for static images (mean: 63%) and gait (mean: 67%), which are approaching the scores (71%) reported in the review by Pollick et al. (2005).

For point-light displays of conducting movements, conversely, observers did not reliably tune into this information. Observers were thus not able to judge the same performers' gender for which they correctly identified gender in gait or static images. Conducting point-light displays were presented from a frontal perspective with the same size dimensions as in gait or static images, thus structural cues related to body shape were available in the same way. Hence our findings suggest that observers focussed more on motion cues than on structure in conducting movements, otherwise the available structural gender cues would have been utilised. Pollick et al. (2002) showed that the visual system may (unconsciously) neglect or fail to detect available information for gender recognition.

The finding that conductors' motor expertise influenced observers' judgments may provide an explanation for the lower gender recognition rate in conducting movements. We argue that the improvement in expert skill leads to higher control and reduces involuntary gender-specific idiosyncrasies. Previous research suggests that violin playing (Konczak et al., 2009) and other complex movement skills (Magill, 2004) become more accurate and consistent (e.g., increased precision, less erroneous) with training. Similarly, practice of musical conducting may shift the movement execution towards an exemplar of technical expertise (*cf.* Wöllner, Deconinck, Parkinson, Hove, & Keller, 2012) that transcends involuntary movement idiosyncrasies and gender-related features, which are present in beginners. Although more research is needed to study the impact of motor training on the availability of gender-specific movements cues, our results indicate effects related to expertise, since only for the group of novice conductors gender recognition was possible. Expert conductors' more refined gestures, on the other hand, potentially limited gender-related movement characteristics and subsequently did not provide observers with sufficient cues for gender discrimination. While kinematic analyses indicate that expertise in conducting did not affect basic features such as total baton trajectory, the smoothness of the motion acceleration signal was higher in experts. Vertical acceleration of the conductor's baton may provide important cues for the conveyance of the musical beat (Luck & Sloboda, 2009) and was closely related to the target beat in a sensorimotor synchronisation study (Wöllner et al., 2012). Our results reveal that this signal is more affected by noise in novice conductors, which is indicative of less fluency and may compromise the perception of the beat. The technical disadvantage shown by less-experienced conductors could in turn have influenced observers' judgments. However, the rather small sample of conductors used in the current study calls for some caution when interpreting these findings. Also, the perception of human conducting is more holistic, including important cues from the conductors' faces (Wöllner, 2008). Yet a great deal of information is already conveyed by point-light displays.

From a social-psychological perspective, the prevalence of gender stereotypes may have shaped observers' responses to some extent. Especially in fields such as music performance, typically characterised by high levels of skill, technique and individual preferences, people often tend to develop distinct social constructs of performing artists (North & Hargreaves, 2008). In the current study, gender stereotyping may have affected recognition accuracy for conducting movements (*cf.* Cox, 2001). Analysis of the observers' response bias and, in particular, "false alarm" rates for experienced conductors, revealed that experienced conductors were more often judged to be male. For novice conductors, on the contrary, no such effect was observed. This effect suggests that observers associated movement skill present in point-light displays of conducting gestures more frequently with maleness. In this regard it can be speculated that conductors are more often taught by male instructors or have a male biased prototype as exemplar, given the domination of males in the field of conducting (Edwards, 2003). These examples could then reflect on both the conductors' movement execution and on observers' expectations of conducting expertise.

Apart from visual judgments of static images, gait and conducting gestures, this study included an auditory-only and an audiovisual condition. The music, two excerpts from the beginning of Mendelssohn's String Symphony No. 9 in C minor, was performed by advanced student musicians, who followed the conductors' gestures closely. Neither for experienced nor for novice conductors the soundtrack itself contained gender-specific cues, in contrast to the visual information provided in audiovisual and visual-only presentations of novice conductors, which facilitated gender recognition for this group. In a recent multimodal integration study (van der Zwan, MacHatch, Kozlowski, Troje, Blanke, & Brooks, 2009), observers judged point-light walkers with ambiguous gender information more often to be female when these walkers were paired with auditory cues related to females. While these findings point to an impact of the auditory modality on perception and gender judgments, in the current study we did not obtain differences or interaction effects for audiovisual as compared to visual-only conditions, suggesting that auditory cues were not relevant for gender judgments. Evidently, musical interpretations differ according to the intentions and personality of individual conductors, and so far it can only be speculated in what ways the conductor's gender may affect the musical performance, if there are general differences at all (*cf.* Edwards, 2003).

Conclusions

Our results indicate that human observers are generally not able to indicate the gender in point-light displays of conductors, particularly if conductors are more experienced. Potential gender cues, which are typically available in other movements such as walking, may thus be diminished for extensively trained technical skills. This effect is dependent on the level of expertise of the conductor. While observers were able to recognise the gender of less experienced conductors, judgments of expert conductors were biased towards male. Overall this research confirms that the capacity of the human visual system for gender recognition in point light-displays depends both on the interaction of automatic mechanisms controlling perception as well as culturally embedded socio-psychological constructs. The musical interpretation in the auditory-only condition did not facilitate gender judgments. Consequently, on the basis of essential movement information and the resulting musical sound, results of this study may also be interpreted as a rejection of overall gender stereotypes in orchestral conducting.

REFERENCES

Abernethy, B., & Zawi, K. (2007). Pickup of essential kinematics underpins expert perception of movement patterns. *Journal of Motor Behavior, 39*, 353–367.

Brainard, D.H. (1996). The Psychophysics Toolbox. *Spatial Vision, 10*(4), 433-436.

Calvo-Merino, B., Grèzes, J., Glaser, D.E., Passingham, R.E., Haggard, P. (2006). Seeing or doing? Influence of visual and motor familiarity in action observation. *Current Biology 16*(19), 1905-1910.

Cho, S.H., Park, J.M., & Kwon, O.Y. (2004). Gender differences in three dimensional gait analysis data from 98 healthy Korean adults. *Clinical Biomechanics, 19,* 145-152.

Cutting, J.E., & Kozlowski, L.T. (1977). Recognizing friends by their walk: Gait perception without familiarity cues. *Bulletin of the Psychonomic Society, 9,* 353-356.

Cutting, J.E. (1978). Generation of synthetic male and female walkers through manipulation of a biomechanical invariant. *Perception, 7,* 393-405.

Cutting, J.E., Proffitt, D.R., & Kozlowski, L.T. (1978). A biomechanical invariant for gait perception. *Journal of Experimental Psychology: Human Perception and Performance, 4*, 357-372.

Cox, A. (2001). The mimetic hypothesis and embodied musical meaning. *Musicae Scientiae, 5,* 195-212.

Davis, J.W., & Gao, H. (2004). An expressive three-mode principal components model for gender recognition. *Journal of Vision, 4,* 362-377.

Edwards, J.M. (2003). Women on the podium. In J.A. Bowen (ed.), *The Cambridge Companion to Conducting* (pp. 220-236). Cambridge: University Press.

Ferber, R., Davis, I.M., & Williams, D.S. (2003). Gender differences in lower extremity mechanics during running. *Clinical Biomechanics, 18,* 350-357.

Findley, J.M., & Gilchrist, J.D. (2003). *Active Vision: The Psychology of Looking and Seeing.* Oxford: University Press.

Gentile, A.M. (2000). Skill acquisition: Action, movement, and neuromotor processes. In J.H. Carr, & R.B. Shepherd (Eds.), *Movement science: Foundations for physical therapy* (2nd ed., pp. 111-187). Rockville, MD: Aspen.

Heinz, G., Peterson, L.J., Johnson, R.W., & Kirk, C.J. (2003). Exploring relationships in body dimensions. *Journal of Statistics Education, 11*, [Online] www.amstat.org/publications/jse/v11n2/datasets.heinz.html

Hill, H.H., & Pollick, F.E. (2000). Exaggerating temporal differences enhances recognition of individual from point light displays. *Psychological Science, 11,* 223-228.

Horton, M.G., & Hall, T.L. (1989). Quadriceps femoris muscle angle: Normal values and relationships with gender and selected skeletal measures. *Physical Therapy, 69,* 897-901.

Konczak, J., van der Velden, H., & Jaeger, L. (2009). Learning to play the violin: motor control by freezing, not freeing degrees of freedom. *Journal of Motor Behavior, 41,* 243-252.

Kozlowski, L.T. & Cutting, J.E. (1977). Recognizing the sex of a walker from a dynamic point-light display. *Perception & Psychophysics, 21,* 575-580.

Johansson, G. (1973). Visual perception of biological motion and a model for its analysis. *Perception and Psychophysics, 14*, 201-211.

Johnson, K.L., & Tassinary, L.G. (2005). Perceiving sex directly and indirectly: Meaning in motion and morphology. *Psychological Science, 16,* 890- 897.

Johnson, K.L., Gill, S., Reichman, V., & Tassinary, L.G. (2007). Swagger, sway, and sexuality: Judging sexual orientation from body motion and morphology. *Journal of Personality and Social Psychology, 93,* 321-334.

Jokisch, D., Daum, I., & Troje, N.F. (2006). Self recognition versus recognition of others by biological motion: Viewpoint-dependent effects. *Perception, 35,* 911-920.

Luck, G., & Sloboda, J.A. (2009). Spatio-temporal cues for visually-mediated synchronisation. *Music Perception, 26,* 465-473.

Macmillan, N.A., & Creelman, C.D. (1991). *Detection theory: a user's guide.* Cambridge: Cambridge University Press.

Magill, R.A. (2004). *Motor learning and control: Concepts and applications* (7th ed.). New York: McGraw-Hill.

Mather, G., & Murdoch, L. (1994). Gender discrimination in biological motion displays based on dynamic cues. *Proceedings of the Royal Society of London B, Biological Science, 258*(1353), 273-279.

North, A.C., & Hargreaves, D.J. (2008). *The social and applied psychology of music.* Oxford: Oxford University Press.

Pelli, D.G. (1996). The VideoToolbox software for visual psychophysics: transforming numbers into movies. *Spatial Vision, 10*, 437-442.

Pollick, F.E., Kay, J., Heim, K. & Stringer, R. (2005). Gender recognition from point-light walkers. *Journal of Experimental Psychology: Human Perception and Performance, 31,* 1247-1265.

Pollick, F.E., Lestou, V., Ryu, J. & Cho, S.B. (2002). Estimating the efficiency of recognizing gender and affect from biological motion. *Vision Research*, 42, 2345-2355.

Pollick, F.E., Paterson, H., Bruderlin, A. & Sanford, A.J. (2001) Perceiving affect from arm movement. *Cognition*, 82. B51-B61.

Pollick, F.E. & Paterson, H.M. (2008). Movement style, movement features and the recognition of affect from human movement. In T.F. Shipley & J.M. Zacks (eds.), *Understanding events: How humans see, represent, and act on events*. Oxford: Oxford University Press.

van der Zwan, R., MacHatch, C., Kozlowski, D., Troje, N.F., Blanke, O., & Brooks, A. (2009). Gender bending: Auditory cues affect visual judgements of gender in biological motion displays. *Experimental Brain Research, 198,* 373-382.

Wöllner, C. (2008). Which part of the conductor's body conveys most expressive information? A spatial occlusion approach. *Musicae Scientiae, 12*(2), 249-272.

Wöllner, C., & Auhagen, W. (2008). Perceiving conductors' expressive gestures from different visual perspectives. An exploratory continuous response study. *Music Perception, 26*(2), 129-143.

Wöllner, C., Deconinck, F.J.A., Parkinson, J., Hove, M., & Keller, P.E. (2012). The perception of prototypical motion: Synchronization is enhanced with quantitatively morphed gestures of musical conductors. *Journal of Experimental Psychology: Human Perception and Performance, 38*(3). Advance online publication: DOI 10.1037/a0028130.