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# Experts see it all: configural effects in action observation

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## Abstract

Biological motion perception is influenced by observers' familiarity with the observed action. Here we used classical dance as a means to investigate how visual and motor experience modulates perceptual mechanism for configural processing of actions. While some ballet moves are performed by only one gender, male and female dancers train together and acquire visual knowledge of all ballet moves. 24 expert ballet dancers (12 female) and matched non-expert participants viewed pairs of upright and inverted point light female and common dance movements. Visual discrimination between different exemplars of the same movement presented upright was significantly better in experts than controls, while no differences were found when the same stimuli were presented upside down. These results suggest expertise influences configural action processing. Within the expert group, effects were stronger for female participants than for males, while no differences were found between movement types. This observer gender effect could suggest an additional role for motor familiarity in action perception, over and above visual experience. Our results are consistent with a specific motor contribution to configural processing of action.

## Introduction

Other people's actions are a rich stimulus, which is of high biological and social importance, but which pose significant computational problems for the brain's perceptual systems. Specialised perceptual mechanisms for movement perception, independent of body morphology, have been studied using point light displays (Johansson, 1973). Limited motion information is enough for humans to identify not only actions, but also emotions (Dittrich, Troscianko, Lea, & Morgan, 1996), gender (Cutting & Kozlowski, 1977), and oneself and friends (Loula, Prasad, Harber, & Shiffrar, 2005), even when local motion information is degraded or masked (Cutting, Moore, & Morrison,1988).

The nature of biological motion perception has been focus of research in many laboratories. A particular interest has been whether biological motion perception is learned through experience. Early developmental studies in children between 3-5 month old were not completely able to fully address this issue because results obtained with infants could always be accounted for by either innate or learning mechanisms. However, a recent study (Simion, Regolin, & Bulf, 2008) showed innate predisposition for biological motion in naïve newborn babies, and more interestingly, this effect was orientation-specific (upright displays were preferred to inverted ones). Despite this evidence for an innate predisposition of the visual system for biological motion, other studies have suggested that action processing may also involve perceptual learning, as do most perceptual functions. Several studies showed better visual processing for human biological actions compared to non-biological, artificial or novel movements (Jastorff, Kourtzi, & Giese, 2006; Pyles, Garcia, Hoffman, & Grossman, 2007; Hiris, 2007), and for one's own or friends' actions compared to strangers (Loula et al, 2005). Biological motion perception might therefore also depend on prior exposure or familiarity with a stimulus. Casile and Giese (2005) showed in an elegant study that making an action, without actually seeing it, is sufficient for such familiarity effects (Casile & Giese, 2005), suggesting that motor expertise has a specific influence on perceptual performance. This result fits with the classical common coding models for action perception, in which representations of external visual input overlap with the observer's own motor representations of the same actions (for a wider view of this model view Prinz, 1997; Hommel, Musseler, Aschersleben & Prinz, 2001). Evidence of motor contributions to action perception has been reported using natural bodies (Knoblich & Flach, 2001), and point lights displays (Loula et al, 2005) in person-recognition tasks.

Moreover, neuroimaging studies of action observation have likewise shown that neural activity is stronger in premotor areas for familiar than for unfamiliar actions, suggesting a role of 'motor resonance' in perceptual effects of expertise (Calvo-Merino, Glaser, Grèzes, Passingham, & Haggard, 2005; Calvo-Merino, Grèzes, Glaser, Passingham, & Haggard, 2006; Cross, Hamilton, & Grafton, 2006). Both visual and motor familiarity play a role (Calvo-Merino, 2006). However, these studies did not focus on how action modulates *perceptual* processing. Neuroimaging studies cannot show whether expertise and familiarity truly influence what people see, or merely how their action systems respond to what they see.

Here, we address this point by investigating effects of previous experience on human biological motion processing, focussing on the distinct contributions of local and configural information processing.

Familiar and biologically relevant stimuli such as faces (Valentine 1988, for a review) and bodies (Reed, Stone, Bozova, & Tanaka, 2003) are processed not only as local features, but also as complete patterns, or 'configurations'. A hallmark of configural processing is the processing advantage for canonical (upright) compared to inverted stimuli. Similar inversion effects have been shown during perception of biological motion. Depiction of point light walkers was harder when presented upside down compared to upright (Sumi, 1988; Pavlova & Sokolov, 2000), suggesting that similar global configuration mechanisms are needed for human motion. Although inversion performance improves with practice (Hiris et al, 2005, Shiffrar & Pinto, 2002), this is due to the use of individual strategies based on local processing of individual dots rather than a contribution of global mechanism for perceiving human figure. Besides faces, bodies and actions, individuals with special expertise show the same inversion effect for specific stimuli where they have acquired perceptual familiarity, such as birds and cars (Gauthier, Skudlarski, Gore, & Anderson, 2000). However, it still remains unclear whether visuomotor expertise influences visual processing of actions in a similar manner.

Here we investigate whether visual and motor expertise influence local and configural aspects of action observation. Because biological motion perception from point-light displays is generally excellent (see Blake & Shiffrar, 2007 for a review), and presumably improves further still in experts, we increased task difficulty by using the very stereotyped actions of classical ballet that allow for only minor individual differences. We used gender-specificity of these actions to dissociate visual and motor familiarity with these stimuli (Calvo-Merino et al., 2006). In classical ballet, a subset of movements is gender-specific. All dancers, irrespective of gender, have extended visual experience with all these actions, because of extensive shared training. In contrast, only dancers of one gender will have motor experience for gender-specific actions. Therefore, we compared visual discrimination performance for dance actions that varied in the degree of the observer's familiarity with the action (expert or non-expert), and in the nature of such expertise (visual or motor). Finally, we compared performance for upright and inverted stimuli, to assess whether any expertise effects were specific for actions presented in the canonical orientation (that would engage configural processing mechanisms), or they represented the use of learned local analysis of the motion patterns, that could be applied both to the canonical and inverted presentation.

## Methods:

***Participants:*** 24 professional ballet dancers (12f, 12m) and 24 aged-matched controls (12f, 12m) with no dance experience participated (age 18–31). Dancers had at least 3 years of professional-level classical ballet experience. All participants were right handed and had normal vision. They gave written informed consent to participate in the study and were paid for participation. The study was approved by UCL Psychology Department's Ethics Committee.

***Stimulus generation:*** Point light displays of standard classical ballet moves were created by modifying Johansson's classical technique (1973). Ballet movements were performed by three professional female dancers wearing tight back clothes to which 13 reflecting markers were attached over major joints and the head. A metronome ensured the dancers maintained a standard pace. With professional choreographic assistance, we selected 8 classical ballet movements, balancing criteria of movement speed, extent of whole-body displacement in space, and whether the movements were specific to female ballet dancers or common to both genders. Several recordings were made of each dancer performing each movement. As ballet movements are very stereotyped, the differences between each movement exemplar were small. Videos were transformed to white dots on black background, and cut to 3 s clips.

We created pairs of videos showing different exemplars of the same ballet movement made by the same dancer. However, these videos could be 1) identical (the second being a repeat of the first video) or 2) different (two different exemplars of the same dancer repeating the same ballet movement on different occasions). The 'different' pairs could therefore not be discriminated by morphological body clues, or by idiosyncratic differences in movement style. Rather, discriminating between pairs of videos required information about the dynamics of the movements per se (intra-individual differences in the execution of the same ballet movement by the same performer) and not about differences between the individuals performing them.

***Procedure:*** Participants judged whether two videos shown in each pair were identical or not. Each trial started with a black screen and a task reminder that lasted 1 s, followed by a 3 s video clip. A scrambled mask of 500 ms followed, to avoid any perceptual imprint, followed by a further video clip. This was obtained by scrambling a series of random black and white squares by means of Adobe Photoshop. The words "same or different" then invited subjects to indicate unspeeded keypress responses (see Figure 1). Each participant had brief initial familiarisation with example stimuli. They then performed six blocks of 48 trials each. Identical pairs and different pairs were equiprobable and randomised. Three blocks showed pairs of point light movies of classical dance in its canonical upright orientation, whereas in the other three blocks the videos were inverted ($180^o$ rotation). Orientation was blocked to encourage a configural mode of processing for upright stimuli. Block order was randomised.

## Results

### *Visual sensitivity and expertise*

Each observer's visual sensitivity for detecting small difference within a pair was calculated as a d-prime value in each condition. A repeated measures 2x2x2x2 analysis of variance (ANOVA) was conducted, with between-subject factors of expertise (expert (dancer); non-expert) and observer gender (female, male), and within-subject factors of dance movement (female-specific, gender-common) and orientation (upright, inverted). We found unsurprising main effects of expertise $F_{(1,44)}= 6.39$; p=.015 and orientation $F_{(1,44)}= 26.44$; p<.001 (Figure 2, Table 1). More interestingly, there was a significant interaction between expertise and orientation $F_{(1,44)}= 26.18$; p<.001. Expert ballet dancers showed better visual discrimination than non-experts for upright stimuli, while both groups showed similar sensitivity for inverted stimuli. We also found an interaction between expertise and observer gender $F_{(1,44)}=4.92$; p<.05. The observer's gender had stronger effects on perception for dancers than for non-dancers. There was no significant main effect of type of dance movements (female-specific, gender common). No other effects or interactions were significant.

We made planned comparisons using paired t-tests to reveal differences in visual sensitivity when the action is presented in its canonical orientation or upside down. We found significantly higher sensitivity for upright stimuli compared to inverted for both female dancers ($t(_{11})=6.19$; p<.001) and male dancers ($t(_{11})=3.30$; p=.007). No inversion effect was found in the controls. Further, in the upright condition, female dancers showed significant better sensitivity than male dancers ($t(_{22})=2.27$; p=.033), than female controls ($t(_{22})=5.02$; p<.001) and male controls ($t(_{22})=4.01$; p=.001). Male dancers' sensitivity in the upright condition was also significantly higher than control females ($t(_{22})=3.42$; p=.002) and males ($t(_{22})=2.25$; p=.035).

However, no group differences were found in the inverted condition. Dancers' visual discrimination benefitted from their expertise only when stimuli were presented in the familiar, canonical orientation.

## Discussion

Our study investigated the role of experience in action perception by comparing movement experts and non-experts in visual discrimination of highly stereotyped actions presented as point light displays. Visual sensitivity measured by d‘ showed that experts were more sensitive than non-experts to the small differences between movements when these were presented in their canonical orientation, while no group difference were found for inverted stimuli. This result suggests that visual perception of biological actions in their canonical orientation may involve configural processing mechanisms, and that this processing is modulated by observer's expertise.

We used gender-specificity of ballet moves to investigate whether visual or motor expertise underlies these perceptual effects. Our female participants had both visual and motor experience of the gender-specific dance actions performed by the female models, while male participants had only visual experience of these moves. We found reliable gender differences in the expert group, where females showed higher sensitivity than males. This effect was specific only for the upright condition and was not present in the control group. At the same time, we did not find any difference between gender-specific and common movements. These two results taken together might suggest that purely *visual* experience of the actions, such as the male dancers in our study had, is sufficient to develop sensitivity to that action within biological motion perception mechanisms. The better performance of female experts could then indicate an additional contribution of motor experience to visual configural processing. This possibility should, however, be considered with caution, because of the lack of significant differences between gender-specific and common moves in the male dancers, and because our study did not include test male and female dancers' judgements of movements performed by males. For example, female dancers' visual discrimination performance might be better than male dancers because the observed moves are always performed by a female dancer. Therefore females might undergo stronger resonance than males with the female dancer's body depicted through the point lights. However, in addition to the question of gender-specificity, our finding of a clear link between expertise and stimulus orientation suggests a strong role of experience in action processing and configural mechanism.

Our result has important implications for action perception in three different ways. First, we tested for the first time discrimination within natural variations across repetitions or exemplars of an action. Other studies have focussed on person-identification or self-recognition (Loula et al., 2002; Cutting & Kozlowski, 1977; Dittrich et al., 1996) or sensitivity to instructed modulations of common motor patterns (Casile & Giese, 2006). In contrast, our participants discriminated *natural variations* of the same action performed by the same individual. Since the actions were highly stereotyped, this strategically pushed action perception to its processing limits, and indeed d' values were generally low. Second, we showed that processing of familiar actions might benefit from configural mechanisms. And finally, these mechanisms are enhanced by previous motor and visual experience.

### Visual and motor expertise enhance biological motion sensitivity

It has previously been reported that motor knowledge is sufficient to perform visual discrimination between different biological motion patterns (Casile & Giese, 2006; Hecht, Vogt, & Prinz, 2001). Here we show that both visual and motor expertise significantly improved discriminating between natural variations of the same action, relative to naïve observation. We also found increased sensitivity in the female dancer group. This sensitivity might reflect an effect of their motor experience was over and above visual experience of the observed actions which they shared with male dancers, or an effect of seeing a dancer of your own gender whose motor experience is closer to your own. The lack of a corresponding difference for the male dancers limits further conclusions. Overall, these results suggest that both visual and motor experience plays a major role in biological motion perception.

Loula et al. (2005) recently reported that visual familiarity enhances biological motion perception. However, their participants had to discriminate between movements displaying strong idiosyncratic differences between individuals, such as free dancing and ball games. Performance dropped when discriminating more stereotyped actions such as walking. Here, we minimised idiosyncratic variability by using trained performers in produce very stereotyped movement stimuli from the classical ballet repertoire, and by requiring participants to discriminate between different performances of the same stereotyped movement made always by the same individual. People often make important decisions based on subtle features of others' actions –and sometimes these features seem barely perceptible. Our result shows that our perceptual system can learn very subtle biological motion perception, based not only on previous visual experience, but more strongly on motor experience.

### *Expertise and configural processing*

Visual discrimination of very stereotyped actions was only possible when subjects had previous familiarity with the observed action, and the stimuli were presented in its canonical orientation. Visual discrimination was extremely difficult for individuals with no familiarity with the actions (control group) in both upright an inverted conditions. Despite the difficulty of the task, expert observers benefited from a different mechanism that increases visual sensitivity to the movements only when these were presented in their canonical orientation. Ever since Yin's (1968) classical paper, inversion effects have been taken as a diagnostic for configural processing. Many studies (using faces) have investigated individual components that might contribute to configural processing or inversion effects: sensitivity to first-order relations, holistic processing, and sensitivity to second-order relations (for a review, see Maurer et al., 2002). Although the design of this study does not allow for such precise inferences, analogy with previous studies of configural and local processing for faces (Valentine, 1988), and bodies (Reed et al., 2003) leads us to suggest that configural processing is involved in observation of familiar movements. Further, we have presented evidence that this mechanism could be enhanced by *motor* familiarity with the observed action. Importantly, the configural information available in our task is information about movement rather than static form on which most previous studies focussed. Our stimuli contained minimal morphological information, this information was equally available to both expert and controls groups) and, we compared movement exemplars performed by the same individual. In these circumstances, configuration is unlikely to be a property of static body morphology. Our results therefore go beyond the static body inversion effect (Reed et al., 2003), and point towards an action-inversion effect.

Configural processing has been identified both with influences of visual experience on perceptual mechanisms (Bukach, Gauthier, & Tarr, 2006), but also with an innate priority system for perceiving biological relevant stimuli (Farah, Rabinowitz, Quinn, & Liu, 2000). Here we show evidence of a possible configural mechanism for *action* processing, over and above other possible parallel mechanisms for configural body processing depicted through the point lights. The surface form of these stimuli was presumably not highly familiar to our participants. However, dancers, who had previous visual and particularly motor experience of the underlying actions showed clear inversion effects, while non-experts did not. These results suggest that visual action patterns constitute a distinct domain of perceptual learning, and the representations learned go beyond the surface visual characteristics of the image portraying the action.

We suggest that when observers recognized movements in their canonical orientation, they automatically use a different mechanism for perceiving -such as configural processing- that facilitates performance. To this extent, the human brain must contain a distinct category of action representations, distinct from body representations. These representations are characterised by configural rather than local detail. When an action is unfamiliar, we might use low-level strategies (for example comparing the relative position of individual dot pairs) to accomplish the task. This last process appears to be common to experts and non-experts, and is available whatever the stimulus orientation.

## ***Conclusion***

In summary, this study provides experimental evidence that a specific configural perceptual mechanism boosts biological motion sensitivity when we observe actions that are familiar. This mechanism might be tuned differentially when the observer had previous motor knowledge or visual experience with the observed action. Crucially, our design shows that this mechanism processes specific *actions* rather than individual actors, static body morphologies, local visual details or superficial visual properties of action images. To this extent, our data support the concept of actions as a distinct perceptual class, processed by specialised functional modules. Further studies may investigate the relation between these functional modules and specialised areas or circuits in the human brain that are activated by observation of familiar actions (Calvo-Merino et al., 2005; Buccino et al., 2004). Dedicated mechanisms for processing the actions of conspecifics are vital for social interaction. The strong roles of prior motor and visual experience, and of canonical orientation, in our study suggest that this development occurs at the level of individual experience rather than at evolutionary scales (Heyes, 2003). Finally, we show that the configural action perception mechanism benefits from both visual and motor familiarity with the observed action. Importantly, our data suggest a specific influence of acquired motor representations on basic visual discrimination processing, over and above purely visual familiarity effects.

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**Table 1**: d’ mean values for performance in upright and inverted conditions as a function of observers’ expertise (expert (dancer); non-expert) and gender (female, male) and within-subject factor of dance movement observed (female-specific, gender-common), and orientation (upright, inverted).

**d’ mean values**

| Orientation | Dance movement | Expert (dancer) | | | | Non-expert (control) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Female | | Male | | Female | | Male | |
| | | Mean | *(SD)* | Mean | *(SD)* | Mean | *(SD)* | Mean | *(SD)* |
| Upright | Gender-common | 1.01 | *(0.55)* | 0.44 | *(0.39)* | 0.13 | *(0.41)* | 0.29 | *(0.40)* |
| | Female-specific | 1.03 | *(0.60)* | 0.75 | *(0.51)* | 0.12 | *(0.31)* | 0.18 | *(0.60)* |
| Inverted | Gender-common | -0.09 | *(0.48)* | -0.11 | *(0.50)* | 0.02 | *(0.35)* | 0.22 | *(0.52)* |
| | Female-specific | 0.04 | *(0.27)* | 0.00 | *(0.46)* | 0.18 | *(0.48)* | 0.29 | *(0.51)* |

**Figure 1:** Schematic of a typical upright and inverted trial. Pairs of videos showed same or different exemplars of the same ballet movement performed by the same dancer.

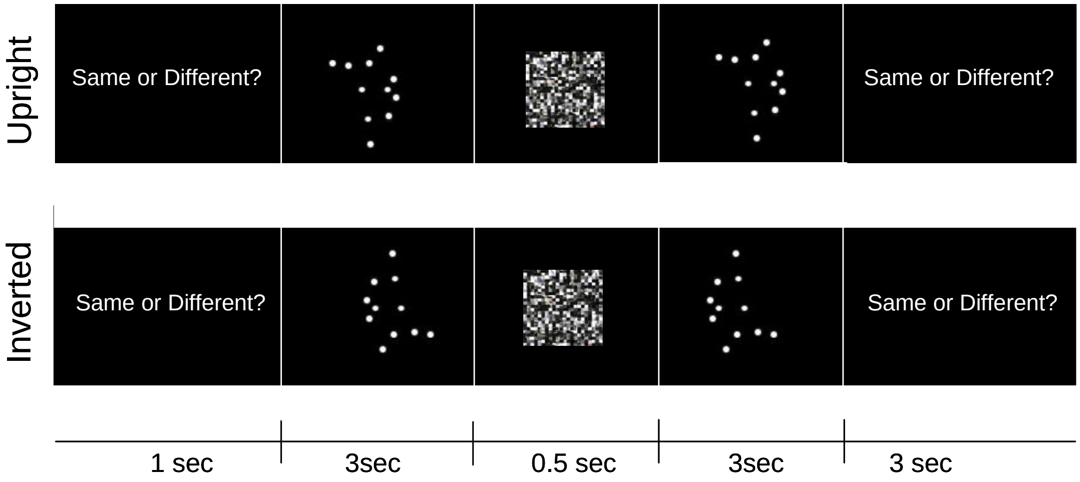

**Figure 2:** d' as a function of factors of participants' expertise (dancer/non-dancer), gender (female/male) and stimulus orientation (upright/inverted). Vertical bars indicate standard error. For simplification purposes, common and gender specific dance movements have been combined. See Table 1 for full information.