INBETWEEN THE SCORE AND THE DANCE: COGNITIVE PROCESSES IN READING LABANOTATION

by

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Introduction

A Labanotation (LN) reader infers movement from a score. Leg and arm gestures are extracted by combining the direction symbols with their location on the staff. The subsequent gestures of particular limbs define the movement. This information has to be transformed to the reader's own body and egocentric perspective. This is merely a vignette of what happens when a score is transformed to movement via the reader's or the dancer's body. Clearly, several other features that have to be considered in defining the entire process of encoding LN. However, the main issue here is that reconstructing movement by reading a notation score is a cognitive process.

Cognition

Cognition refers to the processes of thought. After a long period of investigating human perception, scientists became more and more interested in the brain processes associated with human movement. The focus nowadays is strongly set on action observation and motor control. A moving body needs muscles that can contract and nerves that send the commands to the muscles. However, voluntary movement also requires the brain to prepare and send motor commands to the muscles. For example, when a dancer is mentally rehearsing a movement pattern or when a dancer is watching other dancers moving, certain brain areas named motor and premotor cortex are activated. Interestingly, there seem to be a common brain area responsive for the observation and the execution of a movement. Rizzolatti and Fadiga (1998) found evidence that observing a movement and executing the same movement are firmly connected in a particular brain area. This area (F5) of the premotor cortex is activated either when a monkey observes a goal-directed movement executed by somebody else or when he himself executes the same action. The authors hypothesize that the activation of a corresponding 'mirror system' in humans represents actions that we see other people making.

Often, LN readers report that they generate a mental representation of the movements when reconstructing the movement from the notation. Therefore, it can be assumed that reading a dance notation eludes movement related brain areas even without having any real external movement. However, is internally processing a LN symbol cognitively identical to observing the corresponding movement of another's body? This paper endeavours to explore how this question should be answered.

Labanotation

Investigating cognitive processes between the notation and the dance might have some advantages for the LN community. To know the reading and writing processes in more detail means to be able to infer and make predictions about what happens between the notation and the dance. This knowledge can help to give some directions in the evolution of the notation score and the use of it. However, some particular features of the LN are also of interest for cognitive neuroscientists. First, the LN is perspective dependent, written and read from a first person perspective. Second, the segmentation of the body in LN is not congruent with the segmentation of the physical body. This means, there is no match in the outline of the human body and the graphic symbols on the staff. The way in which the body is represented on the staff is not isomorphic. Third, the movement is given by incrementally indicated positions. This paper focuses on the perspective and the body congruency.

For example, one might ask whether skilled readers *automatically* transform notation into representations of body postures. If there is behavioral evidence that encoding LN to movement is an automatic process, motor observation related brain areas are likely to be activated. Another important issue in the reading process is the *perspective transformation.* The notation symbols can be translated from the staff to the reader's own body (egocentric perspective) or the dancers' bodies (exocentric perspective). When the LN reader aligns the symbols with a representation of its own body, we expect no perspective transformation. The LN represents the body from the back which can be easily matched with the subjects own egocentric perspective. However, imagine the LN reader holding the score in his hands while facing dancers who should learn the movements. In this situation, a perspective transformation from the score - or the readers' egocentric perspective - to the dancers' orientation in the exocentric space is needed. We assume that this egocentric transformation functions like a mental rotation in depth, with a vertical axis trough the body midline in upright positions. Recent studies found that bodies are processed differently if they are presented form an egocentric perspective or an exocentric perspective (Jola & Mast, 2005). Therein, the way dance notation specifies body in space can give insight into cognitive processes while encoding the symbols.

Dance and Cognition

Dance movements are whole body complex three-dimensional movements in space. It has been tagged out in recent experimental studies on motor control and body image that dance represents a decent stimuli (Brown, Martinez, & Parsons, 2005, Calvo-Merino, Glaser, Grezes, Passingham, & Haggard, 2005, Jola & Mast, 2005). Dance movements stands out from other movements as they are object-unrelated with specific syntax (e.g., arm positions in classical ballet). However, to use applied fields like dance in experimental-based research the research of interest has to be narrowed down immensely. For example, in most of the methods where the brain activity is measured, the subjects cannot make whole body movements (fMRI, EEG, TMS). Therefore, studying the cognitive processes involved in reading the LN widely broadens the field. The notation score can be used as a control in experimental settings when the subjects shall not move.

For the moment, we have focussed on using LN to study cognitive representation of the body. The main issue of this paper is to make use of the LN and its particular characteristics to study features of the body representation. It is possible, that LN readers benefit from a wider understanding of the cognitive processes that are involved in reconstructing movements and postures. Our work uses LN to study cognition, and does not prescribe how LN should be used. The dance notation is used to gather relevant information about how the human brain deals with its own body in three-dimensional space.

Posture-matching Experiment

Posture is a term used corresponding to the term position in dance. The matching of two body postures has been used in studies on body representation (e.g., Ramsay & Riddoch, 2001). Before studying movement representation with the use of the LN, it is necessary to investigate basic processes in encoding the symbols. We therefore performed a posture-matching experiment to understand the brain processes involved in reconstructing movements from a notation score.

When a movement pattern is reconstructed from the score, the reader encodes the symbols to a body posture with a particular spatial orientation. How long does the composition from the symbols to a body posture take? How do we deal with the orientation difference in space from bodies and the LN? Both questions can be answered by a simple computer experiment based on findings in earlier investigations on bodies and objects.

From a study conducted by Shepard and Metzler in the 1970s we know that human can mentally transform objects (Shepard & Metzler, 1971). Subjects were presented abstract cubes in different angular disparity on a computer screen. The task was to judge whether the cubes were identical or not. The increase in the subjects' response time with increasing angular disparity between two identical cubes has been taken as evidence for a mental transformation, i.e., a mental rotation of the objects. This is known as the classical mental object rotation task. No such linear increase in response time was found in following studies where the inanimate objects were replaced by pictures of human bodies (e.g., Zacks, Ollinger, Sheridan, & Tversky, 2002). With the evidence form further studies, the authors assume that the bodies were processed by particular brain areas responsible for the perception of bodies (Downing, Jiang, Shuman, & Kanwisher, 2001; Grossman et al., 2000). In contrast, Mast & Jola found evidence for mental body rotation (Jola & Mast, 2005). Subjects had to detect which arm of a body drawing is outstretched. The body was presented from different perspectives (front vs. back) and in different orientations (0°/45°/90°/135°/180°). When the stimuli were presented in the first person perspective, i.e., from the back, subjects showed a clear increase in response time with increasing angular disparity. However, stimuli presented from the front showed no clear increase as bodies inverted by 180° were surprisingly quick to perceive. Most subjects verbally described this stimulus by referring to a feeling of "slipping back". This finding suggests that the subjects' egocentric perspective does play a role in the perception of externally represented bodies.

A posture-matching experiment with the LN will give further insight on the role of the outline of the externally represented posture. In this experiment, subjects have to match two sequentially presented postures. The postures are presented from the front and back perspective. The prime posture (i.e., first presentation) will always be shown by a picture of a dancer. The target posture (i.e., second presentation) will be presented either as a picture of a dancer or as a LN drawing. The general aim of the pilot study presented here is to test if the chosen postures can be matched with a LN. If the LN can be read and correctly matched with the postures in the pictures, we can infer the LN reading time. The LN reading time is given by the difference in response time from trials with the LN in the target from trials with pictures only. Furthermore, we will see differences between picture-LN and picture-picture matches in perspective transformation. The data presented here are from a pilot study. For further results see the original literature Jola & Haggard (in prep.).

Experimental design

Subjects

Two female subjects volunteered to participate in the pilot experiment. Both subjects were students from the professional diploma course in dance studies at the Laban Centre London and had just currently started LN study (approx. 20 hours lectures).

Stimuli

In this pilot experiment we used 4 classical ballet and 4 novel 'contemporary-like' postures (Table 1). The performer was naïve in respect to the hypothesis of the study. The pictures were taken with a digital camera at the Laban Centre. The background of the pictures was homogenate. The LN drawings were written with the computer aided software CALABAN LT (http://aweb.bham.ac.uk/calaban/). No direction signs were used in the LN as they always indicated postures from the back only. This was explained

clearly to the subjects. The notations were verified and rectified for the experiment proper by Jean Jarrell, a Lecturer at the Laban Centre (City University, London).
For each posture 4 modifications were chosen accordingly to balance the criteria of the body parts employed, the body directions in space, the gestures side and alignments (Table 2). In one of the modifications the outline of the modification was virtually matching with the outline of the original posture. In another modification the original picture was mirrored (i.e., lateral change). Furthermore, the original posture was modified with a small change and finally also with a clear change. The small change was defined by a direction and level change of one body limb only. The clear change consisted of a novel arrangement of the LN symbols used in the original posture. This modification resulted in a clearly different posture by upholding the level of information. However, a few symbols had to be changed to remain a biologically possible posture.

Task

The subjects were instructed to match pairs of body postures presented sequentially on a laptop screen. The subjects had to respond by pressing one of two indicated keys with the index finger of the right or the left hand. The response keys for match and mismatch were swapped for every second subject. The task consisted of two matching types, i.e., picture-picture and picture-LN matches, each presented in 50% of the trials. In 50% of the trials, the two postures were oriented in the same direction (e.g., back-back). In the remaining trials, the two pictures were not matching in their perspective (e.g., front-back). As the LN has an inherent perspective from the back, only the back-back and front-back relation were possible. In the picture-picture condition, two more pairs for the factor perspective were randomly assigned (front-front and back-front). We used the additional perspective changes in the picture-picture matching type to prevent subjects from using a preparatory strategy. Thus, no inference about the direction or presentation from the target posture was possible.
In total, the experiment consisted of 256 trials with 8 *body postures*, 2 different *matching types* (picture-picture vs. picture-LN), 2 different *perspective* relations between prime and target (no perspective change vs. perspective change), 2 *congruency types* (same vs. different) and 4 *types of modification* (same outline, lateral change, small change, clear change). The order of the trials was randomized. The prime and the target posture conditions have been swapped randomly (e.g., the original posture could be at the prime or at the target posture). Every 50 trials subjects had the opportunity to take a short break.
The subjects were tested individually in a quiet room. The instruction to the task was standardized and subjects could read them on their own. A brief look at the LN drawings on a paper sheet was offered prior to testing. This assured that the subjects could recognize all symbols occurring in the experiment. Before the pilot experiment started, subjects underwent a training session with five test trials in order to get familiarized with the speed of the task and the type of the stimuli. None of the postures within the test trials

were used in the pilot experiment. The first picture was presented for 1500ms. After an inter-stimulus interval of 500ms with a fixation cross, the second stimulus appeared. The target was presented on the screen for a maximum of 8000ms during which the subjects could give their response.

Hypothesis

We hypothesize that the *reading time* of the LN stimuli is implied in the additional *response time* for picture-LN trials compared to picture-picture trials. Our aim is to show evidence that the LN is encoded into a body representation. The features of the body representation might be similar when generated from pictures. Mental body representations are perspective dependent which can be shown by matching two postures presented from different perspectives. The response time increases when the postures do not match in their perspective. This additional response time represents the mental transformation (see introduction section). When a mental body representation eluded by the LN does share properties of the mental body representation known from recent studies with pictures, we should find a *perspective transformation effect* in both matching types. In this case, additional response time will be shown in both picture types in trials with a perspective change between the two postures.

Helpful information for the experiment proper will be gathered from response accuracy. We test whether the matching types are dependent on the type of *modification* and on the different *body postures* used in this pilot study. For example, when the postures are rated by pictorial given characteristics, postures with the same outline should be less detectable than the other modifications. Finally, the accuracy in the conditions should not differ significantly between the different *body postures*. However, the postures should cover a broad range of different spatial aspects.

Results

We tested the effects of *perspective change* (no perspective change vs. perspective change) and of posture *modification* (same posture, same outline, lateral change, small change and clear change) on *picture form* (picture-picture vs. picture-LN matching). Perspective effects were expected to be shown in response times (RTs in seconds). Effects of posture modifications were tested on the accuracy (in percentage). We computed the analysis with repeated measurement ANOVAS and *t*-tests.

The different body postures were included as a random factor. In a separate analysis we found no significant effect of the different body postures. Any factor that showed significance therefore indicated a general effect that hold over the different body postures. Unfortunately, postures 5, 7 and 8 had to be excluded from the pilot analysis due to programming error and notation inconsistencies. Table 1 shows the mean accuracy and mean RT for the two matching types of both subjects in the remaining six postures. The overall mean accuracy for both subjects was 89% with a standard deviation (SD) of 0.10. Picture-picture matches were identified correctly in 94% (SD = 0.04). Picture-LN matches were correct in 83% (SD = 0.26). The mean RT for both subjects was 1.59 (SD = 0.16) for picture-picture and 3.81 (SD = 1.20) for picture-LN matches.

LN Reading time and Effect of perspective change

Only response times from correct responses were taken. The repeated measures ANOVA with the factors *perspective change* and *picture form* showed significant main effects for both factors and a significant interaction effect, $F(1, 9) = 8.89$, $p < 0.05$ (perspective change), $F(1, 9) = 152.49$, $p < 0.001$ (picture form), $F(1, 9) = 24.20$, $p < 0.001$ (perspective change*picture form). RTs were significantly longer for postures that were not shown from the same perspective, M = 2.56, SD = 1.35 (same perspective) vs. M = 2.85, SD = 1.07 (perspective change). The additional RT for perspective change was significant when the subjects had to match the posture of two pictures, $t(9) = -.30$, $p < 0.001$ (paired samples t-test), M = 1.29, SD = 0.17 (same perspective) vs. M = 1.91, SD = 0.30 (perspective change). There was no significant increase in RT for non-perspective corresponding posture presentations when one of the postures was read from a LN drawing, M = 3.83, SD = 0.48 (same perspective) vs. M = 3.79, SD = 0.60 (perspective change). The mean additional RT for the trials with the LN was 2.20 (SD = 0.13). In both perspective conditions subjects had significant longer RTs in trials with the LN, $t(9) = 14.46$, $p < 0.001$ (no perspective change), $t(9) = 9.14$, $p < 0.001$ (perspective change).

The repeated measures ANOVA with response accuracy as dependent variable and the independent factors *perspective change* and *picture form* showed a significant main effect of *picture form*, $F(1, 9) = 11.77$, $p < 0.05$. The accuracy for picture-picture matches was higher than for picture-LN matches. The effect of perspective change was not due to accuracy trade-off.

Effect of gesture and direction modifications on posture detection

A repeated measures analysis for the factors *modification* and *picture form* shows significant main effects for both factors and a significant interaction effect, $F(1, 9) = 10.1$, $p < 0.05$ (picture form), $F(4, 36) = 4.54$, $p < 0.005$ (modification), $F(4, 36) = 4.58$, $p < 0.005$ (modification*picture form). The mean accuracy was higher when both postures were presented as pictures. However, paired samples *t*-test showed that only postures which had a common outline were significantly better detected in picture-picture than picture-LN matches, $t(9) = 2.86$, $p < 0.05$, M = 90.0, SD = 21.08 (picture-picture), M = 45.0, SD = 43.78 (picture-LN). Postures without any modifications (i.e., corresponding postures) showed a trend for better match from pictures than from LN, $t(9) = 1.92$, $p = 0.09$, M = 97.6, SD = 5.06 (picture-picture), M = 87.7, SD = 15.60 (picture-LN). The higher accuracy of LN drawings to pictures for mirrored gestures did not reveal significance, $t(9) = 1.50$, $p = 0.17$, M = 95.0, SD = 15.81 (picture-LN), M = 85.0, SD = 24.15 (picture-picture). Mean accuracy in picture-picture matches did not vary dependent on the type of modification, $F(4, 36) = 1.36$, $p = 0.27$ (modification). When one of the postures was presented as a LN drawing, the modification type did not have a significant effect on the postures detection, $F(4, 36) = 6.24$, $p < 0.001$ (modification). Post-hoc *t*-tests showed that the low accuracy value in the same outline modification was responsible for this effect. Both subjects did not detect the mismatch when the postures had the same outline in body postures 4 (both subjects), posture 1 (subject 1), and posture 3 (subject 2).

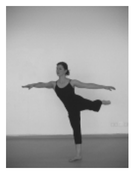
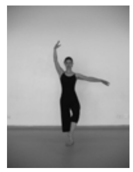
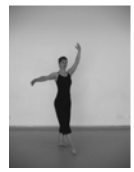
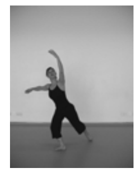
Body Posture						
Accuracy (%)	Picture-Picture	93.8	93.8	96.9	93.8	90.6
	Picture-LN	84.4	90.6	84.4	75.0	81.3
Response Time (s)	Picture-Picture	1.72	1.58	1.64	1.40	1.60
	Picture-LN	3.68	3.58	3.47	3.86	4.45

Table 1. Mean accuracy in percentage and response times in seconds for the two picture matching types, picture-picture and picture-Labanotation. On the left side are the four ballet positions and on the right side the two contemporary postures. Two of the contemporary postures had to be excluded and are not presented here.

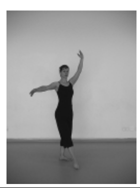
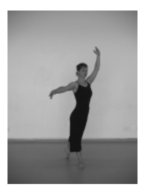
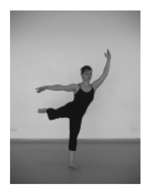
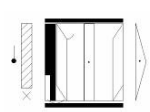
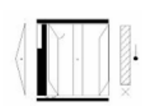
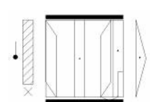
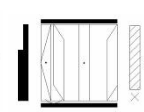
Posture Example						
						
Modification		Same posture	Same outline	Lateral change	Small change	Clear change
Accuracy (%)	Picture-Picture	97.9	87.5	79.2	87.5	100
	Picture-LN	78.1	45.8	95.8	79.2	95.8
Response Time (s)	Picture-Picture	1.67	1.50	1.81	1.51	1.24
	Picture-LN	4.03	2.85	3.60	3.79	3.73

Table 2. Example of an original posture on the left and its modifications used in the pilot experiment. Mean accuracy is given in percentage and response times in seconds for both matching types, i.e., picture-picture and picture-Labanotation (N = 2).

Discussion

Labanotation reading time and perspective transformation

The time needed to match a picture of a body posture with a LN drawing was slightly more than twice as long as the time needed to match it with another picture. This difference in time reflects the *LN reading time*. That is, subjects transformed the symbols of the LN into a mental body representation which took approx. 2s longer than from a picture. However, and crucially for present purposes, there was no additional mental *transformation time* for the LN. For picture-picture matches we found significant longer RTs when the two postures were presented from a different perspective than when the perspective was identical. This result confirms previous findings on egocentric body transformation and mental object rotation (see introduction). The additional time needed is considered as the mental transformation time to adjust the objects or to transform the egocentric perspective. In our experiment, we found a "quick flip" of perspective for the LN condition. Response times did not differ between non-perspective and perspective matching trials when one of the postures was encoded from a LN drawing. However, what does the main result of this study, namely the lack of additional mental transformation time in the LN means?

One possible interpretation for the quick perspective flip is that a mental body representation generated from the LN is perspective independent. In recent literature on mental rotation Murray et al. found a quick flip when one of the stimuli was inverted by 180 degree (Murray, 1997). Murray used familiar objects in her experiment. In a recent study on mental object and body rotation a similar flip was found for inverted bodies (Jola & Mast, 2005). Interestingly, the response pattern seems to be consistent even when the subjects' postures were modified. Shorter RTs were found for inverted bodies from the front view compared to the usually easier back view for bodies when subjects were lying on their back (Mast, Zaehle, Long, Jola, & Lobmaier, 2006). In respect to those studies it is considerable that the characteristics of the mental body representation evoked by the LN reflect a kind of familiarity to the subject that the pictures do not.

However, one argument against the "quick flip theory" is that the mental transformation time is hidden in the additional reading time. This means, cognitive processes may overlap each other. In this experiment, it is doubtable that the cognitive load decreased with increasing difficulty. We found that the encoding of an external stimulus into a mental representation from a LN drawing was cognitively more demanding than from a picture. This was shown by the LN reading time. There is no evidence why reading and the transformation could have shared the same time window that the reading process required for itself. Therefore, we assume that some sort of facilitation does take place, either at during the encoding of the symbols or at the stage of the perspective transformation.

Representation transformation

In the picture-LN matching type condition, the subjects had difficulty seeing the mismatch when the two postures had a common outline. For mismatching postures with similar outlines, the accuracy was significantly lower in the picture-LN than in the picture-picture condition. None of the other modifications showed a significant effect on the accuracy between the two matching types and none of the modifications showed a significant effect on the accuracy within the matching type. We did not expect to find an effect of this modification type only. Some of the body postures could not be identified by the subjects as different at all. However, one posture differed in the level of the supporting leg and the bending of the upper body part, two postures shared the same outline but the side of the supporting leg and the direction of the leg gesture were changed, and another posture was modified by a different direction of the arm gesture while keeping the outline. Only the latter body posture was expected to be difficult to detect. The direction of the arm gesture was not very clear on the picture and could therefore be misinterpreted as a performance error. However, the other postures were clearly mismatching on the picture as well as on the LN drawings. The low accuracy value showed that the symbols from the LN drawing were transformed into a mental body representation which evoked a body image based on visual features at an early stage.

We found that the LN took more time to encode than a picture. However, the LN enables a quick flip in perspective which is not given by mental body representation generated from pictures. This quick flip appears to be a consequence of the egocentric perspective built in to LN. Therefore, the cognitive processes from reading the LN to a mental body representation cannot be simply explained by an additional reading time. Furthermore, we found that different postures which share the same outline were hardly detectable from a LN drawing. This indicates that the encoding of the LN to a mental body representation is closely connected to visual features.

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