

Thinking with Images in Dance Practice

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Abstract

The problem of thinking with images in dance practice is an interesting issue not only for dance researchers but also for cognitive scientists. A question arises: "is thinking with external and internal mental images necessary in dance practice?" Based on the concepts of philosophy, cognitive psychology and neuroscience, various aspects of mental images used by dancers will be discussed. I use different types of thinking with images to argue that the application of external and internal images by dancers which have strong or less correlations influences and improves both dance creation and learning.

Keywords: Dance, Body Image, Mental Images, Motor Imagery, External

1. Introduction

A dancer's practice is based on working with various kinds of images – internal and external ones, which facilitate dance learning and creation. By internal images I understand all the ways of imagination, presenting something in the mind, while by external images I understand various types of external representations (which are not only "extension" of our mind, e.g. reflection in the mirror). Depending on a type of an

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image, it can minimize cognitive or physical effort. Both types take an active part in dance practice and there are correlations between them. There are many studies related indirectly to the thinking with images in dance practice ((Calvo-Merino (2010); Kirsch (2010, 2011); Franklin (1996)) but it is still unknown which of the types has more correlations between internal and external images. In this discussion I will consider various sorts of internal and external images in dance which are used in dancer's everyday practice and I will argue that internal images are indispensable elements of thinking in dance practice. Firstly, I will present the primal view of thinking with images referring to the body – Gallagher's body image and body schema. Then, starting from Plato's concept of 'mimesis', I will indicate several perspectives of this notion which show the ways of using internal and external images. The role of Action Observation Network will also be discussed in the context of external representations of dance (such as a video). Next, to justify the claim that dancers use mental imagery to relieve physical effort, I will discuss the concept of motor imagery. It will be also elaborated using external representations – a tool which reduces cognitive effort. Then, I will consider an instance of Naharin's GaGa movement language in which external representation could interrupt dance creation.

Lastly, I will present the investigation relating to dance marking proposed by David Kirsch. The general aim of this paper is to highlight the fact that thinking with external and internal images in dance practice has stronger or weaker correlations - depending on a situation.

2. Body image and body schema

The body image and body schema concepts have repeatedly featured in philosophical and cognitive works ever since Munk (1890) and Wernicke (1900) claimed that there were 'images' stored in the sensorimotor cortex. Thereafter, the notion of 'schema' was used by Bonnier (1905) to describe a spatial quality associated with awareness of the body in space. Head and Holmes (1911) defined body schema as a postural, preconscious model of the body. Schilder (1935) regarded concepts of 'body schema' and 'body image' as synonymous. Merleau-Ponty (1962) used *schéma*

corporel notion in his *Phenomenology of Perception* and took a phenomenological perspective to conceptualize the dynamic functioning of the body. Many authors have taken up the issue of image and body schema (i.a. Meuse (1996); Straus (1970)) and many of them have noticed ambiguity of these concepts (Shontz (1969); Poeck and Orgass (1971)), (cf. Gallagher, 2005:19-22).

Shaun Gallagher decided to clarify this distinction in his *How the Body Shapes the Mind* (2005) for better understanding of our embodiment. According to the author, body image and body schema are the systems which correlate with each other in the context of an intentional action. Body schema embraces the ability of moving and maintaining posture. These motor skills are almost automatic and unconscious. In the article *Body schema and body image in a deafferented subject* Gallagher and Cole describe the body schema as follows:

The preconscious, subpersonal processes carried out by the body schema system are tacitly keyed into the environment and play a dynamic role in governing posture and movement (Gallagher & Cole, 1995:371).

Body image is a system that includes beliefs, mental representations, attitudes about one's own body. Body image is available to our consciousness. This system contains a form of reflective or self-referential intentionality (Gallagher, 2005: 24-25). There are three types of these intentional contents:

1. Body percept: the subject's perceptual experience of his/her own body;
2. Body concept: the subject's conceptual understanding (including folk and/or scientific knowledge) of the body in general; and
3. Body affect: the subject's emotional attitude toward his/her own body. (Gallagher, 2005:25)

Despite the distinction between body image and body schema, the former can affect the latter. In terms of dance, the body schema is a holistic, sensorimotor experience which is necessary in a dancer's work. The body image can affect both positively and

negatively a dancer's work. If a dancer is aware of his or her body limitations, then there is less chance of injury. When a dancer realizes his or her weakness, for example poor flexibility, he or she can also try to work on these weak points. There are also negative aspects of perception of (especially young) dancers such as anorexia or bulimia. Appearance and weight are very important in the work of professional dancers. Mirror is then an inseparable element of their work. Their body image is constantly subjected to self-criticism and external evaluation; therefore, it often changes. Awareness of appearance of a dancer, mirrored by his or her dance, also can affect his or her motor performance. A dancer who practices hip hop dance (which has strong cultural background) can feel not so good in his or her own body during dance without a cap, big blouse and baggy pants. In contrast, a contemporary dancer will feel properly in a tight costume in the colour of skin or being naked to express his or her freedom and a pure form of movement, free from the symbolism of clothing.

Body image and body schema are the primal concepts of thinking with images in dance. Dancer's body image which can only involve physical appearance or could be more emotional, influence dancer's body schema. This approach to the general thesis of the paper demonstrates that even at the most basic level – looking at a dancer's own body produces a certain image of him- or herself, which affects the performance of dance. It is worth noting here the studies on the ability to imitate movements or gestures which refer to the theory of *mimesis* and Action Observation Network (discussed in the next part of the paper).

3. Mimesis in dance

Since most of a dancer's work is built on imitating choreographer's movements, a reference to the theory of *mimesis* seems appropriate. The concept of *mimesis* appeared in Plato's writings. He distinguished two variants of *mimesis*:

1. Imitating the external appearance which boils down only to sensory data.
2. Imitating the idea which is made by a person who has 'love of wisdom'. Such imitation leads to truth and goodness (Plato, 2003, VI-VIII)

A division closer to the cognitive sciences was proposed by Marc Jeannerod (2006). He distinguished between imitative mirroring and true imitation. The first refers to the ability to duplicate an observed action and to imitate the external aspect, that is appearance of the subject taking part in the common action. True imitation is the ability to understand the intentions and purpose of another agent. Owing to this ability, it is possible to repeat an action to achieve a specific goal (Jeannerod, 2006:121).

Both types of mimesis are used by dancers. Dancers learning from a choreographer perform an action like imitative mirroring – they imitate the “look” of a movement, copying the steps of the choreographer. They operate on images of the teacher which are stored in short-term memory. However, such ~~an~~ imitative mirroring can lead to an empty form of dance and a mechanical reproduction of movement without any spiritual involvement. In contrast, a true imitation occurs when a dancer is learning a dance phrase, during which the choreographer presents his or her vision – a story that dancers must show and the emotions accompanying the creation of choreography. In such a situation, mental images of dancers are induced by the choreographer's instructions and may differ from each other, which may enhance the creative, distributive process of creating dance in a group. Using true imitation to form the performance, it is easier for dancers to understand the choreographer's intentions and perform them in front of the audience. Then presentation of the choreography on stage is more valuable and can affect the audience in the way the choreographer has planned.

The concept of *mimesis* can be interpreted in a different way through analyzing contact improvisation.² It does not refer to the imitative mirroring but consists in finding a common goal that allows a common action with the same intention. In this case, the similarity occurs not in the dance steps performed by the dancers but in the intent of their movement. Another case of mimesis can be seen in pure improvisation that occurs, among others, in the process of making performances, for example used by Wayne McGregor and Ohad Naharin. Referring to the techniques of improvisation, Tomasz Ciesielski (2014) introduces the concept of mimesis of ideas, which he defines as:

² Contact improvisation – a dance technique in which the points of physical contact with another dancer are the beginning of movement improvisation

(...) recognizing and surrendering to the same idea or intent of doing in reality (...) in contrast to the contact of improvisation, this imitation may have nothing to do with compatibility of physical movement and intentions (Ciesielski, 2014:78)

These different types of mimesis point out that imitation process during dance practising leads to creation of images in a dancer's mind. When imitative mirroring is used, a dancer duplicates external image of the movement through imagination and recreates it so, there is dependency of external and internal structure. While true imitation is used, mental images of the dancers are different and depend on their interpretation but lead to the common goal. Using mimesis of ideas, the common aspect is only the idea, the mental images can vary significantly from each other.

4. Action Observation Network

According to Emily S. Cross (2010), Action Observation Network is a general term which encompasses brain areas such as: *supplementary motor area, ventral premotor cortex, inferior parietal lobule and posterior superior temporal sulcus*. The Action Observation Network encompasses canonical neurons that are responsible for representing the features of objects, such as shape or image, activating appropriate motor activities, simulation neurons that code for abstractly targeted activities and neurons that code the movement.

In *Neural Mechanisms of Seeing Dance* Calvo-Merino and collaborators (2010) present their results of research regarding the observation of dancers. The first study involved three groups: classical dancers (ballet dancers), capoeira dancers and a control group of people who do not dance. Groups were passively watching films presenting ballet or capoeira during functional magnetic resonance scanning (fMRI). It turned out that the mirror neurons strongly activated while people were watching familiar movement. When the dancers watched the dance films with their repertoire, the areas of the observation network were stimulated. It was the same situation in the capoeira group. In the control group, there was no such an increase in activity. Researchers have

found that there is integration between the observation of an action and the repertoire of one's own motor behaviour, which indicates that the brain 'sees' activity through motor experience.

Another study conducted by Calvo-Merino (2010) together with other scientists consisted in checking a similarity between a dance video observed and an experience of movement. The activity observation network was examined during observation of activities. Participants of this study were male and female professional classical dancers. Because in the ballet certain figures are characteristic only for men (e.g. *tour en l'air* or *révoltade*), and some movements are performed only by women (including *révérence* or *fouetté*), the researchers decided to show the dancers the recording of the opposite and the same sex, keeping in mind the fact that they are visually acquainted with all the figures, because they usually train together. Movements performed by a group of dancers of different sex were also shown. It turned out that at the moment when men watched choreographies made by men, the areas of the observation network were more strongly stimulated. A similar situation occurred in women. The authors conclude (Calvo-Merino, 2010: 161-163) that the actual physical experience is a prerequisite for activating the observation network. The brain "perceives" an activity through motor experience. Observation of dance with strong motor familiarity activates brain areas of Action Observation Network more than observation with only visual familiarity. These studies show that not only internal, but also external representations of dancer's body could influence his or her action. A video with a dancer's movement is used to improve memory abilities to remember a dance phrase providing that it refers to the dancer's motor repertoire. It is a good memory method to revise a bit for example when a dancer is having a rest.

5. External representations in dance

External representations are visible and used in our everyday life almost at every step. Drawing a structure of a complex problem on a piece of paper, planning a route using a map or looking at a calendar – these representations, among other things, are used to decrease the burden of our work memory, and thus, reduce the cognitive effort.

External representations are an indispensable tool of a dancer's work. They reduce cognitive effort and allow him or her to share thoughts with others. According to Kirsch (2010):

(...) they change the cost structure of the inferential landscape; they provide a structure that can serve as a shareable object of thought; they create persistent referents; they facilitate re-representation; they are often a more natural representation of structure than mental representations; they facilitate the computation of more explicit encoding of information; they enable the construction of arbitrarily complex structure; and they lower the cost of controlling thought—they help coordinate thought (Kirsch, 2010: 441).

In 1928 Rudolf Laban, a well-known dance theoretician, created kinetography – a dance notation system which graphically showed different aspects of a dance such as movement intensity, direction or duration. Thanks to this system, dancers in various places around the world could faithfully recreate choreography. These external representations of dance enable concentration on particular aspects of movement. External representations allow a person to share thoughts with others. Using external structures, one can communicate and analyze movement.

William Forsythe is a choreographer who has also used external dance representations in dance practice. He presented a graphical representation of movement in a video using graphical lines on his body. These lines formed different geometric figures that changed their shape as he moved. Thanks to such a graphical representation of the process of making a move, dancers can easily understand how to perform it step by step. The choreographer, manipulating his body in various directions, shows how the supervisor moves on the transformation of a figure. Thanks to the three-dimensional graphic representation, a group of performers together with the choreographer share the image of the body control to achieve the goal of a given movement. In addition, all participants have a common reference point. This method helps dancers imagine a movement through showing them images directly and doing re-representation. These

external images bring internal images in dancer's mind.

Another example of using external representations by choreographers is drawing crosses on paper forming representations of a dancer's location on stage. This practice is widely used by choreographers to make it easier to plan changes in the position of dancers on stage and create an attractive 'choreographic drawing.' This method is especially useful when one has to plan the position of a large number of dancers on stage. The external representation of a dancer's placing enables the choreographer to manipulate easily the dancer's position changes and decrease his or her cognitive effort. Creating choreography for many dancers is a logistical activity. Presenting this with the help of pictures greatly facilitates a choreographer's work. However, before external representations are created, a dancer must imagine representation in the mind, so external and internal representations could be treated jointly.

6. Motor imagery in a dancer's work

Before a dancer makes a move, he or she presents it on the mental level using his or her motor imagination. Motor imagery can be understood as motor simulation, which activates the motor system in the absence of motor realization (Jeannerod, 2001, 2006). Thanks to motor imagery, a dancer has the ability to analyze step by step the technique and order of movements. This idea of movement also improves memorization of dance sequences. A dancer may strive to perform a dance as it was in his or her imagination.

According to Tadeusz Sankowski, there are three basic functions of motor imagination: programming, training, regulating (Sankowski, 2001:56). The programming function is related to the design of motion realization in the imagination for later reproduction. The training function is used for repetition and consolidation of movements. Movements are repeatedly "performed" mentally in order to master them. The regulating function is designed to control and correct movement during its implementation. For example, during a dance, a dancer checks his or her movements comparing them with those imagined. The above functions complement each other. It also happens that they overlap. There are two levels of motor imagery: the final and the actions that are necessary to carry out a given activity (Sankowski, 2001:57). Before a

jump, the dancer imagines the next elements: preparation - *chasse*, *plié*, jump and final position after jumping in the *plié* position.

The concept of motor imagination is closely related to the theory of simulation. The theory of simulation states that:

(...) motor imagination is an externalized operation in cortical motor centers, simulating offline the course of a specific body movement. Motor imagination is a form of subliminal activation of the motor system (Francuz, 2007: 221).

As indicated by empirical data (Jeannerod, 2001), motor imagination activates brain centers responsible for movement, such as: premotor cortex, basal ganglia or cerebellum. The theory of simulation does not explain how the internal process of imagination takes place. It only informs that imaginative processes are a form of free activity of premotor areas that do not involve the skeletal-muscular system (Francuz, 2007: 222). Nevertheless, motor imagery is an important tool of a dancer's work and shows that thinking with mental images supports the dance practice.

7. From ideokinesis to GaGa movement language

A heavy back injury of Mabel E. Todd, the pioneer of ideokinesis, led to implementation of this method which gave rise to recovery of her motor skills. She described the ideokinesis method in *The Thinking Body. A Study of the Balancing Forces of Dynamic Man* (1937). Ideokinesis consists in projecting mental images in motionlessness. The principles of biomechanics and anatomy are the basis for the development of precise mental images. As Bernard (2006) claimed, mental images are used to enhance pattern of muscles function. Sweigard (1978) decided to expand the method of ideokinesis. She defined ideokinesis as “repeated ideation of a movement without volitional physical effort” (Sweigard, 1978:187). She began a study to check the influence of mental images on measurable changes in the skeletal alignment. Sweigard (1978) invented nine lines of movement of the body along which the changes taking place. According to the author, imagery of movement is an important action of

the central nervous system (CNS). During concentration on the idea of movement, the CNS “chooses” the most effective neuromuscular coordination for its performance (Sweigard, 1978:6). Franklin (1996) points out that there is not only one type of mental images and proposes exact distinction among: visual, kinesthetic, proprioceptive, tactile, olfactory, auditory, gustatory (Franklin, 1996: 49-51). Mental images can also be divided into direct and indirect imagery. Direct imagery is a nonverbal representation of a movement which is actually performed (Overby,1990). It is, for example, visualization of stretching a rubber band. Indirect imagery is metaphorical and is used when, for example, our representation of the arm is substituted by a metal tube.

Ohad Naharin – artistic director of Batsheva Dance Company and author of GaGa dance language – is a choreographer who often uses indirect imagery in dance practice. Contrary to Mabel Todd, he claims that cognition takes place in action and while making mental images dancers should dance continuously. GaGa language is a system of instructions which help a dancer (or people who not dance professionally and take part in GaGa/people class) find new ways of moving through exploration of his or her own body. Here are some instructions to learn before the first GaGa lesson:

The class is one session without pauses, based on a series of overlapping instructions. It is important not to stop while the teacher is giving instructions or in the middle of the session. This allows us to develop our ability to listen to our body while receiving the instructions(...). Gaga's instructions guide us to first listen to the body and to discover its range of sensations (...)

GaGa is not a dance technique – it is a language so we should consider it a system of signs in the de Saussurean way of thinking. In this case *langue* will be a general system and *parole* will be the concrete instructions or performing. GaGa language is used for communication between choreographer and dancer and between dancer and his or her body. One of the main commands are *shaking* and *floating*. *Shaking* refers to a shake of the whole body and *floating* is connected with a concept of water flow in the

³ <http://gagapeople.com/english/about-gaga/work-instructions/>

body or moving in the water. GaGa is based on improvisation with teacher's instructions. These instructions made by Ohad Naharin are very metaphorical and motivate a dancer to create abstract mental images:

"Become spaghetti in boiling water";

"Find the snake in your spine";

"Feel your blood moving through your body";

"Find the moons in your body, in your hands, on the back of your neck, etc. ";

"Boil your body; it's 80-90% water; shake so that you boil your body";

"With each step, plant a seed and feel the flower grow up through your body to blossom somewhere on the surface of your body"⁴

While dancers perform specific movements motivated by the instructions of the teacher, we can see a manifestation of image schemas (Johnson, 1987) which determine abstract metaphors that appear at the level of statements and movements.

They arise as a result of dancers' sensorimotor experiences. Image schemas refer to experiences of space and they are the basis for metaphors used by dancers and choreographers. Orientational metaphors (Lakoff & Johnson, 1980) are the particular kind of metaphors used by – among others – GaGa dancers. They refer to spatial bodily experience such as, for example: up-down, front-back, in-out. Orientational metaphors are rooted in our physical and also cultural experience – they could differ from cultural and individual experience (Lakoff & Johnson, 1980: 18-19). In the *Metaphors We Live By* (1980), Lakoff and Johnson noticed:

⁴ Michael J. Morris Thoughts of Batsheva and Gaga, 11 II 2009, <https://morrismichaelj.wordpress.com/2009/02/11/thoughts-on-batsheva-and-gaga/>

In actuality we feel that no metaphor can ever be comprehended or even adequately represented independently of its experiential basis. (Lakoff & Johnson, 1980: 19)

Concept UP appears in many metaphors, such as HAPPY IS UP or MORE IS UP. These metaphors have a different experiential basis. Various kind of bodily experiencing relates to verticality, so despite the same concept, the metaphors vary between each other.

The fact that distinguishes GaGa classes is the explicit ban on using mirrors. In other types of dance (such as classical ballet, jazz dance, hip hop), mirror is an inherent part of the dance practice. Looking at each other in a mirror while dancing helps improve dance technique. However, Ohad Naharin has a different point of view on this topic. According to the choreographer, lack of a mirror induces dancers not to control their movements, not to duplicate their own motor habits, but leads them to looking for new qualities of movement and pushing their own limits. As Naharin said:

Our weaknesses, our strengths, our sexuality, our intelligence, our awareness of the universe have a lot to do with how we dance (Figge Fox:2009)

He claimed that a dancer's history and experiences are reflected in their movement. Absence of a mirror during the GaGa lessons lets dancers unlock the way of looking at dance: from planar and unidirectional to three-dimensional. GaGa lets them explore the whole kinesphere (Laban, 1956, 1966) and liberate the head from looking in one direction. In an interview with Wendy Perron (2006) Ohad said:

I want to say: Abolish mirrors; break your mirrors in all studios. They spoil the soul and prevent you from getting in touch with the elements and multi-dimensional movements and abstract thinking, and knowing where you are at all times without looking at yourself. Dance is about sensations, not about an image of yourself (Perron, 2006).

In terms of thinking with images in dance, GaGa is a special kind of dance practice. First of all, teachers create instructions which are, according to Franklin's distinction, indirect and abstract imagery (Franklin, 1996: 51-53). These instructions, which are very metaphorical, make GaGa dancers produce mental images inspired by teachers' instructions. Using these mental images, they create a movement. Because GaGa is based on improvisation, probably there is a tight temporary coupling between mental image and movement. But what happens with external images during dancing GaGa? If there is no external image of the body reflected in the mirror, then this image cannot have an impact on the dancer's thinking during creation of a movement. The only external images that can affect dancers' imagination are another dancer's movements which could be a stimulus to find new movements in his or her body and environment (which are usually blank walls and covered windows). By external structure we can also understand teacher's instruction. Thinking with images in GaGa is only one case in which external image reflecting in the mirror of one's own body do not improve creation and practice of dance. According to Naharin, looking at oneself in the mirror disturbs making a dance, discovering oneself, using all spatial dimensions and pushing the kinesthetic and personal boundaries. In the context of Shusterman's work (Shusterman, 2000), in which he distinguished two aspects of working with the body, we can categorize GaGa more as experimental, not performative. According to Naharin, the quality of movement experience is more important than external appearance issues of the body in dance. He claimed that dance must be not beautiful and absolute. External image of a dancing person in the mirror deranges the process of creating movement. Nonetheless, use of internal images is intensified by picturesque, metaphorical instructions which can be treated as external structure.

8. Marking – internal or external process?

Marking is a tool which dancers use to save energy, focus on some aspects of a dance phrase or avoid tough elements such as jumps. Marking is sketchy performing of a movement in a simplified form. According to Kirsch (2011), marking is used for communication, coordination in duos or larger groups and it is also a mechanism of

thought. In the paper *How Marking in Dance Constitutes Thinking with the Body* (2011), Kirsch distinguished three types of marking: marking-for-others, marking-for-coordination and marking-for-self (Kirsch, 2011:182). In marking-for-others and marking-for-coordination the role of marking is to have a common reference for all dancers and facilitate communication, coordination and joint attention. A question arises: “why dancers are marking-for-themselves instead of mentally simulating”? According to Kirsch (2011), marking-for-self facilitates exploration of a dance phrase more than mental simulation. In this case, marking creates an external structure which is connected with thought. This external structure gives a dancer a scaffold to make more extensive and specific mental images and allows to create more complex mental operations (Kirsch, 2011:199). Marking is an example of using external and internal images jointly to improve dance practising. Externalization of thought enhances focus on complex aspects of the movement. The external structures give more details to work on than mental images.

In marking, thinking by external structure plays an important role in dance practice and, both with internal simulation, empowers dancers’ thought. Furthermore, Kirsch investigation (2013) of marking, mental simulation and full-out in which dance phrase learning was measured under the criteria: technicality, memory, timing, and dynamics, indicate that marking is the most efficient method of dance practising:

1. Marking is the most effective overall method of practicing, being slightly more learning efficient than practicing full-out across the key dimensions of Memory, Technique and Timing; (mean difference = .31; $p = .0189$). In dynamics, however, full-out is better.
2. Both marking and full-out lead to substantially more learning than mental simulation across all dimensions; (mean difference = 1.19; $p = .0001$).
3. Mental simulation is not a strong form of practice; there was negligible learning and in many cases practice by mental simulation led to a decrease in performance (Kirsch, 2013: 17)

This study demonstrates that not in every case of dance practice mental simulation

prevails. In this case, there is strong dependency between internal and external images which improve dance learning.

9. Summary

In this paper I have analyzed different types of thinking with images which are inherent tools of a dancer's work. Both internal and external use of images plays an important role in dance improvement. I have argued that internal images and external images have different correlations dependency of varying degrees in dance practice depending on a situation. Movement of a dancer is influenced by his or her body image which includes beliefs, mental representations, attitudes about one's own body. Creation, repetition and correction of dance take place through internal processes of manipulating images such as motor imagination. External processes and tools such as kinetography, graphic representation of movement on a film, or drawing the position of dancers on a piece of paper also improve dance creation and learning but they are not necessary. All these methods support a dancer's work and allow him or her to focus on movement. I have investigated different ways of thinking with external and internal images which improves and influences dance practice. There are situations in which external representations are unnecessary and in others are desirable. In GaGa dance, external representation of one's own body does not have a good effect on the creation of movement. A dancer uses only internal images to make a movement and the only external object which can influence his or her movement is another dancer or a setting. It does not change the fact that using all types of images in dance creation is an indispensable element of a dancer's work. In dance marking, especially marking-for-self, externalization of thought plays the crucial role in focusing on details and exploring the dance phrase. Marking is a common tool used by dancers in everyday dance practice. It is the best method to learn a dance phrase. In this case, external structure takes an active part as well as internal, mental simulation and there is a strict dependency between them.

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