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The Influence of the Visual Representation of the Notation System on the Experience of Time among Young Music Players

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ABSTRACT

Music notation embodies the metaphor of music as motion in time and space (Johnson & Larson, 2003). Notes can be viewed as analogous to objects along the route defined by the musical staff. As such, principles of motion may be used in the translation from the visual information of the notation (length and density) into realized time, creating possible biases related to our experience of motion in space.

In the current study[1] we measured the playing tempo of 61 children (aged 6.9-14.4) who performed and verbally responded to a set of musical examples presenting various manipulations on the length of the staff and the density of the written notes. In order to determine their developmental stage the children were also tested for weight conservation and time perception (Piaget, 1969).

Results indicate a clear influence of the manipulated variables on playing tempo when manipulations were applied to the entire staff, but not when limited to a single measure. In general, short and/or dense visual information led to faster tempi. This was obtained despite an explicit understanding of the irrelevance of these variables to the temporal interpretation of the notation, and could not be explained by participants' developmental stage, or ability to maintain a steady beat. Moreover, even priming with a metronome did not abolish the effect. We discuss implications for our understanding the metaphor of time-space and motion in music, and implications for music pedagogy.

I. INTRODUCTION

Music is the art of organizing sounds in time. Music measures the rhythm of the musical events and their changes, and thus not only constructs time, but also creates the illusion of movement. The idea according to which music describes analogies of physical movement is perhaps one of the most influential in the theory and aesthetics of music, and is reflected in our discourse on music and on musical notation as a visual expression of the flow of music (Cox, 1999; Eitan & Granot, 2004; Honing, 2003; Scruton, 1977; Zbikowsky, 2002). If music is perceived as movement (albeit a fictitious one), it is plausible that the perception of time in music will reflect principles pertinent to the perception of time in actual physical movement that occurs in space.

The present study aims to show that the visual information in musical notation – most notably the length of the staff and the density of the notes along the staff, are mapped to motion in space, and this mapping influences the playing tempo in reflecting thereby the mapping from physical motion to the musical one.

While the temporal dimension can only be imagined, the spatial dimension is clearly perceivable and much less abstract. Therefore, the human concept of time is largely based on the concept of space. This association also finds expression in language; in various languages, time and movement are often referred to in terms of space, whether we "look forward to a better tomorrow," "propose theories that are ahead of their time," or "lag behind schedule," we rely on terms from the realm of space (Casasanto, et al, 2004: Gentner, Imai & Boroditsky, 2002).

The cross domain mapping from space to time is one of the examples of a more general phenomena termed *conceptual metaphor*, through which whole areas of human experience are conceptualized systematically in terms of other areas of experience. Lakoff and Johnson (1980) suggested that the human conceptual system is constructed around a limited number of concepts that grow directly from physical experiences, and includes, for example, a set of spatial concepts (such as up-down, forward-backward), a set of physical ontological concepts, and a set of experiences that involve basic action (such as eating or motion). A key concept in their theory is the notion of dependence upon physical experience (embodiment), or what they call "embodied realism" whereby thinking arises from the body and meaning depends upon sensory-motor experience. That is, physical interaction with the environment is of crucial importance to cognitive processes.

The basic relationships of meaning, whose source is physical experience, are borrowed and transferred to domains of intangible content, such as emotions, thoughts, ethics, logic, economics, social relations, governmental institutions, and others. There is a two-way connection between language and thinking, which strengthens the influence of the conceptual metaphor; thinking influences language and leads to the use of terms that are shared by the source and target domains, while the use of these terms reinforces the connection and extends the boundaries of the mapping. Thus for example there are bidirectional influences between physical sensation of warmth or cold and social proximity (Ijzerman & Semin, 2010; Zhong & Leonardeli, 2008), between physical cleanness and moral judgment (Schnall et al, 2008; Zhong & Liljenquist, 2006), between physical size and judgments of importance (Valenzuela & Soriano, 2008)

[1] This study is based on the PhD dissertation of T. Yovel

and between physical space and happiness (high = happy) (Casasanto & Lorenzo, 2006).

Movement involves going from place to place, and as such it involves the passage of time. A change in location in space also means a change in "location" in time. Consequently, an analogy is created between movement in time and movement in space, and this body-dependent connection between the two engenders the time-space conceptual metaphor. Since the source of the association between time and space is actual experience, it is internalized automatically and unconsciously. If we add to this the fact that time is an abstract concept, difficult to understand, while the dimensions of space are tangible and observable, we can begin to understand why time is often perceived in terms of space. Within this framework, two central models describe the possible relationships between time, space, and the human observer (Boroditsky, 2000; Gentner, 2001; Matlock, Ramscar & Boroditsky, 2003). The first, "the time-moving model", assumes a stationary observer with time passing by her, as reflected in expressions such as "the coming week" or "the past year". According to the second model – "the self moving model" the viewer comes from the past and moves through the present in the direction of the future, while time, as a point of reference, remains stationary. The self-moving model is reflected in phrases such as "we are getting closer to the golden age" or "we have left the worst behind us". This model is compatible with our view of the flow of time: the observer, as part of the world, moves in the "right" direction, from the past to the future, and also allows us to conceptualize time in terms of kinesthetic experience.

Johnson & Larson (2003) presented three important musical movement metaphors: the "moving music" metaphor (corresponding to the time-moving model), metaphors of "the musical landscape" (corresponding to the self-moving model), and the metaphor of "the observer perspective," which is perceived as a faraway point of view, from which it is possible to observe the path through which the musical surface delineates a certain musical piece. Johnson and Larson show how each of these metaphors stems from a specific basic experience of physical movement and physical forces, and how the logic whose source is in physical movement shapes the logic of musical movement. According to them, our conceptualization, our discourse, and even our experience of musical movement depend on these three metaphors.

While sound evolves over time and creates illusory movement, musical notation does occur in space and involves some real spatial aspects. Written notes are first and foremost a guide for skilled and educated performers. In other words, they are a kind of shorthand that provides the foundation and skeleton of the musical piece to be played. The role of the symbol is to serve as a trigger for action. However the mapping between the visual information (stimulus) and response is largely arbitrary, and requires explicit knowledge of the cultural notational conventions. Contrary to what children and adults with no musical training think (Tan, 2002; Tan, Wakefield & Jeffries, 2009), bigger note-heads do not indicate stronger intensity; Dark note-heads are not longer or stronger than white note-heads; and most relevant to our study, smaller distances between notes do not point to smaller "temporal distances" (i.e., faster tempi). Generally speaking, the "location" of notes on the "timeline" in musical notation does not provide relevant information regarding their duration. Rather, duration and tempo rely on formal knowledge regarding the relationship between the beat, its subdivisions and multiplications, and how the different durations relate to each other. However, the length of the path (staff) and the density of the landmarks (notes), although irrelevant to the temporal interpretation of the played music, may influence it through rules applied from real motion whereby long paths take longer than shorter ones, and density of objects along the path reflects shorter distances and/or faster motion.

In light of the above, musical notation, both in terms of theoretical understanding and in terms of practical performance (in playing), presents a unique case study for the exploration of the influence of the time-space conceptual metaphor on thinking and action.

While the time-space conceptual metaphor seems to be a good candidate to explain children's behavior when interacting with musical notation, other factors should also be taken into consideration, most notably the children's cognitive development stage. According to Piaget's theory of developmental stages, the development of thinking occurs in stages, and each stage is different than the last in terms of quantity and quality (Piaget, 1969). The stages of development are fixed, universal, and none of them can be skipped. Each individual goes through the stages of development in the same order, but the duration of the steps varies from person to person. Piaget understood development as the formation of a stable balance between the child's cognitive system and the outside world. The development of the understanding of time according to Piaget is consistent with the developmental stages of thinking, and parallel to it in its division into stages.

The stages relevant to this research are the second part of the pre-operational stage, which is the "stage of intuitive thinking" (ages 4-7), the "concrete operations stage" (ages 7-12), and the "formal operations stage" (age 12 and over). A child at the intuitive thinking stage focuses on one dimension, the one most prominent in a given situation, and lacks the abilities of conservation and reversibility, that is, mentally reconstructing the previous stage of action. At this stage, children define concepts of time, speed, and distance exclusively through the stopping points of objects (Arcedolo & Schmid, 1981; Casasanto, Fotakopoulou & Boroditsky, 2010; Siegler, 1981). Piaget argued that at this stage, children's concepts of time are not distinct from their notions of space, and thus are affected by them. Therefore, it may be assumed that a child at this stage will have difficulty in understanding the principles of musical notation, will be affected by the prominent dimension in the situation before him (such as the density of elements), and will have difficulty in judging duration and tempo, which require the weighing of data and logical thinking.

In the next developmental stage, the concrete operations stage (ages 7-12), the child can think logically, less rigidly, and more flexibly, and has a better ability to operate logical and systematic thinking that uses many pieces of data. The child can relate to several dimensions of the same stimulus at the same time, and can also draw conclusions about changing situations. Children at this stage do not base their judgment on appearances alone. They do not necessarily identify a superficial appearance with reality, and are better able to perceive the reality behind appearances. This ability is also relevant to the understanding of time, because it facilitates understanding of the complex relationship between speed-time-distance (Levin, 1982; Levin, Gilat & Zelniker, 1980). At this stage, children should understand the principles of musical notation quite well. In the formal operations stage (ages 12-18), which is the most developed stage of human thinking according to Piaget, there should not be any difficulty in understanding the principles of musical notation.

According to Piaget's theory of cognitive development, children reaching the concrete operations stage should show understanding of the principles of musical notation such that the irrelevant visual information in the notation will not influence their experience of time. On the other hand, if we take into consideration the theory of conceptual metaphor, which draws a connection between time and space as evidenced by data from numerous empirical studies on this subject (Casasanto, 2007; Casasanto & Boroditsky, 2008; Casasanto et al., 2004), we can assume that even when understanding exists, the unconscious influence of the analogy between (fictitious) movement in time and movement in space will affect the experience of time. Therefore, our goal is to demonstrate that even participants who are at a developmental stage that enables a proper understanding of musical notation as a system of symbols, and who do show such an understanding as reflected by their verbal responses to examples of musical notation, are influenced by the irrelevant visual information in a way that corresponds to principles of movement in space.

II. METHODOLOGY

In the current study we examined how different visual cues influence the temporal interpretation of musical notation among 61 Children. We obtained data regarding their tempi in playing a selection of especially written musical examples; we examined their explicit understanding of the notational conventions; and we tested the developmental stage at which they are found. We expected to find a relationship between the visual display (the independent variable) and the tempo of the performed music (the dependent variable) — a relationship that arises from the perception of the musical staff as a timeline that documents movement whose interpretation corresponds to the principles of the perception of motion in space. Furthermore, we hypothesized that this relationship would be expressed even when the participants demonstrate cognitive abilities and/or explicit understanding of the principles of musical notation that should reduce or eliminate the effects of the visual display on the tempo of the playing.

In the study we presented 20 musical examples testing various aspects of the hypothesis. Here we focus on three such examples which demonstrate the methodology and the main findings relevant to the entire study.

Participants

Sixty-one children aged 6.9 to 14.4 years (M = 10.6, SD = 2.2), who had been playing various musical instruments, including the recorder, the flute, the piano, the electric organ, the guitar, the violin, and the drums for an average of 1.8 years (range = 1- 4 years; SD = 0.97), participated in the study.

Materials and Procedure

Testing participants' developmental stage

The developmental stage of each child was tested using two tasks: a weight conservation task and a second task related to the understanding of distance-speed-time relationships. Both conservation ability and the understanding of time are cognitive abilities that characterize the concrete operational stage, but do not characterize the previous stage, the intuitive stage. In the weight conservation task, two pieces of plasticine of equal weight and shape were presented to the participants. The participants were told that the pieces of plasticine had been weighed previously, and were of identical weight. Next, the shape of one of the pieces was changed in front of the participants, in such a way that the two pieces now looked different. At this stage, the participants were asked by the experimenter whether the weight of the pieces was identical, or whether now one of them weighed more than the other. An answer that there was no change in the weight of the pieces indicated the presence of weight conservation ability, while an answer that the weight of the pieces was now different indicated the lack of this capability.

In the time-speed-distance task the children were presented with two identical toy buses, and were told that the buses were supposed to start out on their "journeys" from the same given point and at the same time. They were also told that at the end of the buses' journeys, they would be asked whether the durations of the bus rides were the same, or whether one of them lasted longer than the other. The "journey" was carried out by the experimenter, in such a way that she "drove" one bus faster than the other. As a result, the stopping point for the faster bus was farther from the point of origin, even though the two buses stopped at the same point in time (i.e., they traveled the same duration of time). At this stage, the children were asked by the experimenter whether the buses had traveled for the same duration of time, or whether one of the buses had traveled for a longer time than the other. An answer that the duration of the bus rides was the same pointed to an understanding of time-speed-distance, while an answer that the bus that traveled a longer distance had traveled for a longer (or shorter) time indicated the absence of this understanding.

Testing the explicit and implicit interpretation of the musical notation

The understanding of the principles of musical notation was tested using two different tasks: a verbal questionnaire and a visual analogue scale. Participants were shown in each of four examples two musical staves and were either asked verbally to estimate how long would one melody sound as compared to the other (forced choice between "longer", "the same duration" and "shorter) or were asked to draw a line representing the relative duration of the second melody given the duration of the first (represented by a fixed length of line). We used the scores in these four tasks to divide our participants into two sub-groups based on the variable of "understanding": Those generally showing a good understanding of all fours tasks (one or no errors) formed one group (n = 47), whereas those with two or more errors formed the second group (n = 14). The variable of "understanding" was then used as a variable in the ANOVA analyses of the playing tempi.

In addition to the above we tested participants' ability to maintain a steady beat by asking to them to continue tapping for 17 beats following 8 metronome beats of 80 M.M. The results of this part are not derailed here, but we do report the relationship between this task and the main playing task.

In the main part of the experiment, we recorded and extracted the playing tempi (calculated as number of beats per minute) of each child playing on his/her instrument. We examined the overall mean tempo at which the music was played, as well as the mean tempo of selected measures. This was taken as an indirect and implicit measure of interpretation of the notation. The order of the execution of these three tasks in the current study was from the implicit to the explicit (i.e., first playing, then the visual analogy, and last, the verbal questionnaire).

The tasks (except the beat constancy task) were based on the same pool of short melodies written for the purpose of this study. All examples were structured in such a way as to create a dissociation between their interpretation as the documentation of movement in space and their interpretation based on the principles of musical notation (akin to other types of conflicts between perception and conception as in the Stroop effect).

The music was written in 4/4 meter, and included only notes of the following durations: wholes, halves, quarters, and eighths (see Examples 1-3). The specific pitch contour of the melodies was used to create a sense of melody rather than a bare rhythmic pattern, and has no direct bearing on the research question. The simple composition of the melodies (from the musical point of view) was designed to reduce, as far as possible, the influence of the level of playing skills. Melodies contrasting along a selected feature (e.g., length of staff) were presented in pairs or triplets shown on the same page as demonstrated in Examples 1 to 3. Two versions were created for each example such that in half of the examples the shorter or more densely written staff was presented at the top of the page, and in the remaining examples, the order was reversed. In examples 1 & 3 half the children (n = 30 or 31) were assigned to each of these orders. In example 2 all children (n = 61) played both orders, but with interpolating material, so that the two versions were never played consecutively.

Two non-orthogonal variables were used in order to visually manipulate the visual display of written notes ("the images of the path"): the relative length of the staff and the density of the notes along the staff. Examples were generally divided into two kinds of conditions. Under the first condition, the visual difference between pairs of melodies was apparent along the whole "image of the path". That is, the participants were exposed to a difference in the overall picture of the melodies (see examples 1-2). This was a prominent difference that could be perceived at first glance, even without processing the details of the example. Under the second condition, participants were presented with pairs of melodies in which the difference between them was specific, and expressed in only a small part of the staff (for example, only in one of four or five measures). In addition, in some examples, participants heard, prior to playing each example, a metronome set to 80 M.M. We hypothesized that the presence of auditory priming would eliminate or reduce the influence of the visual information.

In melodies 1a-1b (Example 1) the independent variable was density, and it was applied across the entire staff. Half the children were presented with the sparsely written notation appearing at the top of the page (as seen here in Example 1) whereas the remaining children were presented with the same melodies in a reverse order (not shown here, indexed as 1c-1d for further reference).

Example 1: melodies 1a-1b. The independent variable is density of written notes across the entire staff.

In melodies 2a-2c (Example 2) both density and length were manipulated, such that the shortest staff was also the most dense. All children (n=61) played the melodies in the order shown here, as well as in a reverse order (from the least to the most dense), although never as two consecutive examples. In addition, these same three melodies were presented to participants twice (though never consecutively) with the second presentation preceded by auditory priming of 8 beats of an 80 M.M. metronome (we refer to these as melodies 22a-22c). In the analyses we only compared the most dense and shortest melody to the longest and least dense (e.g., 2a and 2c, without examining 2b).

Example 2: melodies 2a-2c and 22a-22c. The independent variable is the density of the written notes across the entire staff *and* length of staff. Examples 22 were identical but tempo was primed by 8 beats of an 80 M.M. metronome.

Finally, melodies 3a-3d (Example 3), demonstrate change in density applied to a single measure rather than to the entire example. Half the children were presented with the sparsely written measure (m4) appearing at the top of the page (as seen here in Example 3) whereas the remaining children were presented with the same melodies in a reverse order (not shown here, indexed as 3c-3d for further reference).

Example 3: Melodies 3a-3b a single manipulated measure at the middle of the melody

In the analyses we either compare the tempo of parallel measures (e.g., first four measures of Example 1a with the first four measures of Example 1a) or the tempo of a given measure with previous measures within that same melody (e.g., measure 4 to measure 3 in Example 3a or 3b). We use the mean beat values, or the difference (or proportion) between two beat values.

III. FINDINGS

Figure 1 presents the percentage of participants in each age group erring in each of the four tasks that did not involve playing: Visual analogue and verbal responses regarding the relative expected duration of pairs of melodies, weight conservation, and understanding of time-speed-distance relationships.

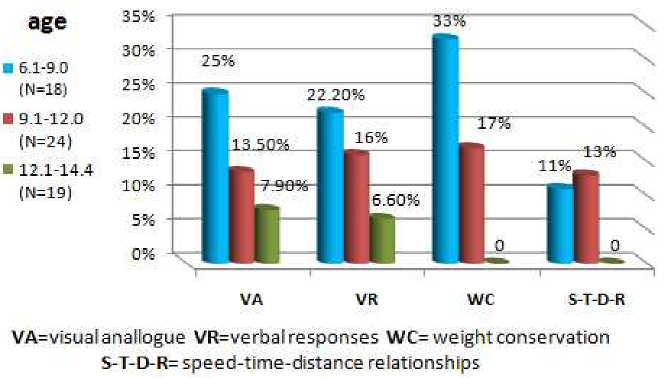


Figure 1. The percentage of participants in each age group erring in each of the four tasks that did not involve playing.

Overall, the percentage of children who erred in any of the tasks is relatively small with the weight conservation task eliciting the largest number of errors (16.4% of all participants). As expected, the percentage of participants providing incorrect answers in all tasks is significantly reduced with age.

In general, both the terminology and the explanations in the erroneous verbal answers depended for the most part on concepts from the realm of space. For example, one answer stated "because in melody 1b the notes are closer together and that which is closer together is faster". In other words, the shorter distance was interpreted as a shorter duration of time. Another example of this phenomenon is found in the following answer: "Since the measures in 2a are longer it will take longer to complete this melody". These responses indicate that the visual display provided the participants with information that was mapped to motion and then (incorrectly) applied to judging duration.

Among a minority of the participants, the influence of the spatial layout as an "interfering factor" was evident, even when the developmental stage was determined to be a stage that enables understanding of the principles of musical notation and the meaning of the spatial layout in it. Thus, despite the fact that among participants from the older age group, not even one error was observed in the weight conservation and perception of time tasks, 7% to 8% of these children did provide incorrect answers in the direct questions on the interpretation of the musical notation examples.

We now turn to a more detailed description of the results in each group of melodies.

Detailed Results in Melody Group 1a-1d

In this group of examples, 51 out of 61 participants performed the measures written more densely faster than those written more sparsely. This amounts to 83.6% of the tested participants and is a statistically significant portion (z-statistic = 5.248, $P < .0001$). Concomitantly, a comparison of the proportion of the mean tempo across the two melodies with the value 1 (the value expected if tempi is maintained across both melodies) shows a significant effect: The proportion between melodies 1a (mean tempo 89.18) and 1b ($M = 99.97$) is 0.908 and between 1c ($M = 82.23$) and 1d ($M = 94.12$) is 0.902 – both significantly different from the value 1 ($t = -4.59$, $df = 29$, $P < .001$ and $t = -4.11$, $df = 30$, $P < .001$ for 1a/1b and 1d/1c respectively). An ANOVA analysis of the possible effects of Order of presentation, Age and Level of Understanding (as defined above) revealed that none of these influenced significantly the results.

Detailed Results in Melody Group 2a-22c

In this group of melodies we hypothesized that the shortest and most densely written melody would be played fastest, and that this would be evident not only when examining the mean tempo across the entire melody but also when looking at the chosen tempo as reflected in the first measure. We further hypothesized that when the tempo would be primed by 8 beats of an 80 M.M. metronome, the differences between the tempi of the melodies would be reduced or eliminated. Finally we hypothesized that in these examples we would obtain a mean tempo closer to 80 M.M. (the primed tempo) as compared to a freely chosen tempo.

As seen in table 1, in all melodies around 70% of the participants played the most dense melody with a higher mean tempo (i.e., faster) as compared to the sparsely written melody. This is a statistically highly significant percent as measured by the z-statistic. Interestingly, this percentage did not change significantly when the tempo was primed by the metronome beats (22A-22F, as compared to 2A-2F).

	2A-2C	22A-22C	2D-2F	22D-22F
z-statistic	3.20064	3.456817	3.712993	2.944464
p-value	0.000686	0.000273	0.000102	0.001618

Table 1. z-statistic of the percentage of participants whose tempi of playing was consistent with our hypothesis that the shortest and most densely written melody would be played fastest.

An ANOVA on the mean tempi using the variables of density + length (2-levels), order of presentation (shortest and most dense at the top of the page vs. longest and least dense at the top of the page), and priming by metronome (with vs. without) showed a main effect of density and length F (67, 420) = 11.64, $P < .0001$, a main effect of metronome $P < .0001$ and no other main effects or interactions. Indeed when examining the difference in tempo between the two melodies (see Table 2), we see that the differences are smaller when the tempo is primed by the metronome. Nonetheless, the absence of interaction suggests – that these differences are still significant in the hypothesized direction. As can be seen in Table 2 the exact same pattern can be found if we look only at the first measure rather than at the entire melody.

	2A-2C	22A-22C	2D-2F	22D-22F
whole melodies	6.9	3.7	4.0	1.6
first measures	7.1	2.8	4.7	1.4

Table 2. Differences in mean tempo of short staff and densely written notes (2A and 2D) versus a long and sparse staff (2C and 2F), without (2A-F) and with priming og 8 beats of 80 M.M. metronome.

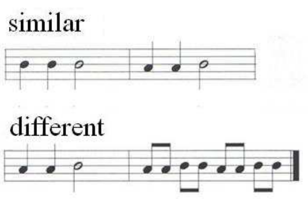
Finally, when the participants were primed by an 80 M.M. metronome, their mean tempo was 84.2 M.M. as compared to 91.0 M.M without priming, suggesting children's natural tempo is faster than 80 M.M. We also found that the mean tempo of the first measure was slower than the overall mean (85.9 M.M. as compared to 87.9 M.M.), suggesting some process of acceleration, seen also in the beat constancy task. In contrast with results reported for melody group 1a-1d, in this group of examples we did find a significant effect of the variable of "understanding" $F(1, 236) = 11.77$, $P < .05$ with a mean tempo difference of 2.99 M.M. between pairs of melodies in those scoring no errors or a single error in the non-playing tasks (weight conservation, distance-speed-time relationships, visual analogue and verbal responses to the musical examples) vresus a much higher difference of 7.85 M.M. in those scoring two or more errors in these tasks.

Detailed Results in Melody Group 3a-3d

As seen in example 3, in this group of melodies the three first measures are similar in terms of the visual display both in the measures' size and the density of the written notes. The manipulation of density and length is limited to a single measure – the 4th one[2]. In this group of melodies none of the analysis measures indicating a difference in the tempo of the 4th measure as compared to the previous three measures of the same melody, or as compared to the 4th measure of the parallel melody yielded significant effects. We did find that the 4th measure, which includes eighth notes as compared to quarter and half notes that were presented in the previous three measures, was systematically played slower (mean tempo of 73 M.M. in the 4th measure as compared to 85.5 M.M. in the previous three measures), suggesting that the number of notes in each measure may also influence the playing tempo.

IV. DISCUSSION AND CONCLUSIONS

The playing task revealed a central and robust finding: measures that are similar in terms of content (number of notes and their temporal value) and spatial layout (length and density) are played at a similar tempo, while measures that are different in these terms (Example 4) are played at different tempi, and contrary to a correct interpretation based solely on principles of musical notation.



Example 4. Examples of visually "similar" and "different" measures

t-tests comparing the tempi of playing of visually similar measures such as the second and third measures in example 3a and 3b, reveals that all such measures are played in a similar tempo. In contrast t-tests comparing the tempi of playing pairs of adjacent and nonadjacent visually different measures (e.g., measures 3 and 4 in example 3a) al reveal a statistically significant difference with P values all < .01.

The influence of the visual display on the tempi of playing was in accordance with the principles of movement in space (and contrary to preserving a uniform tempo) and was notable in the examples in which the manipulation was evident throughout the entire musical staff. Melodies whose spatial layout was short and dense were played at a significantly faster tempo than melodies that were similar in content, but were distributed in a less dense manner over a longer musical staff. This finding was evident even in examples in which the players were primed with 8 metronome beats played at a constant tempo before they began playing. That is, even auditory priming of the beat did not eliminate the differences in tempo driven by the visual information, although it did diminish the size of the effect.

In contrast to the significant influence of spatial layout on the playing tempo in examples in which there was a manipulation of the musical staves in their entirety, a more complex pattern of responses was apparent in examples in which the difference between the two melodies was localized (a single note or a single bar). No effects were found when the manipulated measure was in the middle of the melody, but were observed (data not reported here) when the manipulation was on the first measure of the melody. It would seem that the different pattern of response to the two types of intervention (a difference in the overall manipulation of the entire staff versus a more localized manipulation) can be explained by the prominence of the manipulation: the more pronounced the change was in terms of scope and the initial impression it created, the more influence it had.

Another possible explanation derives its claims from various forms of visual processing: the global and the local. In global visual processing, the shape is perceived in its entirety, while in local processing, visual information is analyzed according to its basic components. Consistent with findings from previous studies (Navon, 1977 ; Hochshtein & Ahissar, 2002), we assume that global processing preceded local processing in such a way that the melodies in each pair were first of all classified as "similar" or "different". In accordance with this classification, the overall tempo and the starting tempo of the melodies were apparently determined. Melodies that differed over the entire image of the path were classified as "different," and their playing tempo was then set to be different – following the rules of motion in space.

Melodies in which there was a specific change were perceived as "similar" in their general appearance, and therefore were played at a similar overall tempo as well as a similar initial tempo. Our model suggests that, a further, local visual processing step occurred in which the information on each staff was processed, with no comparative connection to corresponding information on the staff of the second melody of the pair. On the basis of this processing, differences in tempo were observed in the playing of adjacent measures. Analysis of the data (reported elsewhere) suggests that two factors influenced the tempo curve in examples with local manipulations: the number of notes in the bar had a dominant influence according to which the greater the number of notes in a bar, the slower the tempo, and the visual display on the notes within the measure (how dense they are and the length of the measure) had a secondary influence. The combination of these two factors was found to determine the playing tempo

[2] In a different set of examples the manipulated measure was the first measure of the melody. The results of these examples are somewhat different but their report is beyond the scope of the current paper, and will be reported elsewhere.

The influence of the variables of participants' developmental stage and the measured level of understanding of the notational conventions as revealed by the verbal questionnaire and the analogue scale was apparent under conditions in which the research hypothesis was clearly proven (i.e., the experiments in which the melodies were perceived as "different"). Participants who demonstrated an understanding of the principles of musical notation and who were diagnosed as being in the concrete operational developmental stage ("with understanding") tended to be less influenced by the spatial information than participants who were classified according to non-musical tasks as "lacking understanding". In general, we can say that proper understanding of the notational conventions did not eliminate the misleading influence of the spatial information, but did constitute a moderating factor in terms of the effects of the manipulations on the tempo of playing.

In summary, the results of the current study indicate that the effect of the visual display of the notation on the experience of time, as it is expressed in the selected tempi in playing, originates in the conscious or unconscious perception of musical notation as based on principles of movement in space. Other factors, including the basic ability to maintain a constant tempo when a visual display is not involved, the developmental stage of the participants, and the explicit understanding of the conventions of musical notation as demonstrated by the tasks that did not involve playing, cannot in and of themselves account for the findings. Therefore, the assumption regarding the impact of the visual display as mediated by the relationship between time and space remains the most parsimonious explanation of the patterns of results obtained in the our various experiments.

This assumption highlights the importance of the current study, which adds a layer of understanding to the wide array of research that addresses the notion of conceptual metaphor in general, and metaphors that link time and space in particular. Furthermore, the current study relates directly to understanding the way in which children learn to play from notes, and to the consequences that stem from this understanding. If we assume that the suitability of the notation system can be defined solely in terms of the ability of the performer to interpret it, this study raises a fundamental difficulty. Nonetheless, since we can assume that a change in the notation system is unlikely to occur, the task of mediating between it and the performing student falls on music teachers. A necessary condition for this mediation is teachers' awareness of possible difficulties and their origins, which can be seen as related to the cluster of studies that address misconceptions and their importance in the learning process. This study sheds light on an additional way of relating to this topic.

Based on this newly acquired awareness, it is possible to offer several practical suggestions. The most prominent involve changing the emphasis on the order of learning, so that familiarity with sound and hearing music precedes familiarity with its visual representation. This recommendation is consistent with the well known musical education approach called "sound before symbol". Other possible implications are: a recommendation to use the metronome to dictate tempo, moving the emphasis from the eye (the spatial display) to the ear (the metronome beats), while breaking the connection between the spatial display and the tempo. To this end, experience in playing one musical notation at different tempi or different musical notations at a constant tempo is desirable; the literal use of terms of duration and not terms of space (despite the fact that there is an obvious lack of these in language) to highlight the difference between the two domains; emphasis on establishing the sense of a steady beat in playing from notes; and relating in teaching not only to individual symbols but also to "images of the path" and what they mean. Another implication concerns musical notation and suggests the regular use of proportional writing with the goal of reducing the influence of spatial layout on the experience of time.

Future studies will be able to further establish the relationship between the specific domain examined in the current study and the broad research areas to which it relates, as described above. Such studies will examine the effects of spatial layout on the experience of time in larger and more homogeneous populations. It is also recommended to examine the effects of spatial layout among music students who studied with the assistance of a metronome, those who studied according to the "sound before symbol" method, and so on. There is no doubt that, given the centrality of conventional musical notation in today's musical studies, and in light of the findings of the current study, we should consider comprehensively and extensively how it is perceived and understood among young students of music.

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