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Position coding effects in a 2D scenario: The case of musical notation

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ABSTRACT

How does the cognitive system encode the location of objects in a visual scene? In the past decade, this question has attracted much attention in the field of visual-word recognition (e.g., “jugde” is perceptually very close to “judge”). Letter transposition effects have been explained in terms of perceptual uncertainty or shared “open bigrams”. In the present study, we focus on note position coding in music reading (i.e., a 2D scenario). The usual way to display music is the staff (i.e., a set of 5 horizontal lines and their resultant 4 spaces). When reading musical notation, it is critical to identify not only each note (temporal duration), but also its pitch (y-axis) and its temporal sequence (x-axis). To examine note position coding, we employed a same–different task in which two briefly and consecutively presented staves contained four notes. The experiment was conducted with experts (musicians) and non-experts (non-musicians). For the “different” trials, the critical conditions involved staves in which two internal notes that were switched vertically, horizontally, or fully transposed — as well as the appropriate control conditions. Results revealed that note position coding was only approximate at the early stages of processing and that this encoding process was modulated by expertise. We examine the implications of these findings for models of object position encoding.

1. Introduction

How does the cognitive system encode the identity and the location of musical notes? The usual way to display music is the staff (i.e., a set of 5 horizontal lines and their resultant 4 spaces), which is read from left to right. The notes in the staff represent the relative duration of a sound (e.g., in a 4/4 time, the note 𝅝 is equal to four beats, 𝅗𝅥 to two beats, ♩ to one beat, ♪ to one-half beat). The identity (i.e. the temporal duration) of the notes is attained on the basis of the shape of the note head and the presence/absence of a stem with/without flags. Nonetheless, to correctly identify a given note, it is also necessary to achieve information regarding pitch. Pitch information is obtained from the placement of the notes in the vertical axis. Furthermore, as it occurs during the recognition of visually presented words in left-to-right languages, the information regarding temporal sequence of the notes is obtained in the horizontal axis. Thus, when reading musical notation, the cognitive system has to encode the temporal duration of the notes, their vertical position, and their horizontal position. The simultaneous encoding of the notes along the vertical and horizontal axes is challenging, and it has been claimed that the nature of musical notation “makes it difficult to accurately localize a particular symbol” (Sloboda, 1976, pp. 6–7) and that “exact position is one of the last properties of elements within arrays to be determined” (Sloboda, 1978, p. 324).

Given that research on position coding during music reading (i.e., a 2D scenario) is very scarce, let us briefly examine the vast literature on letter position coding during visual-word recognition and reading (i.e., a 1D scenario). Words are sequences of letters in a horizontal [e.g., English] or vertical [e.g., Japanese] axis. A number of studies, using a variety of techniques (e.g., behavioral, eyetracking, ERPs, fMRI) and languages (English, French, Spanish, Maltese, Basque, Thai, Japanese, Arabic, etc.), have revealed that pairs of visually presented stimuli with transposed letters (e.g., jugde and judge) are perceptually very similar (e.g., Johnson, Perea, & Rayner, 2007; Perea & Lupker, 2003; see Frost, 2012, and Vergara-Martínez, Perea, Gómez, & Swaab, 2013, for recent reviews). For instance, in a word/nonword discrimination task (i.e., lexical decision), participants make substantially more “word” responses on transposed-letter nonwords (e.g., “jugde”) than on control nonwords (“jupte”) in which the critical letters are replaced — note that correct identification times are also longer for transposed-letter nonwords (Perea & Lupker, 2004). Letter transposition effects have been obtained not only along the horizontal axis, but also along the vertical axis (see Witzel, Qiao, & Forster, 2011, for evidence in Japanese). Transposition effects are not specific to word processing: They have been reported with strings of pseudoletters (García-Orza, Perea, & Muñoz, 2010; Muñoz, Perea, García-Orza, & Barber, 2012), symbols (García-Orza et al., 2010; see also Duñabeitia, Dimitropoulou, Grainger, Hernández, & Carreiras, 2012), digits (García-Orza & Perea, 2011; see also Duñabeitia et al., 2012), and geometrical objects (García-Orza, Perea, & Estudillo, 2011). Importantly, transposition effects appear to be restricted to the visual modality: the same stimuli that produce sizeable letter transposition effects during

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visual-word recognition fail to show letter transposition effects when presented in a tactile modality (i.e., Braille reading; see Perea, García-Chamorro, Martín-Suesta, & Gómez, 2012).

Taken together, the above-cited findings are consistent with models of visual attention that assume that there is perceptual uncertainty at locating the position of objects (e.g., letters) in a visual scene (e.g., in a string of letters) (e.g., CODE model, Logan, 1996; see also Adelman, 2011; Davis, 2010; Gómez, Ratcliff, & Perea, 2008; Norris, Kinoshita, & van Casteren, 2010, for similar claims; but see Dehaene, Cohen, Sigman, & Vinckier, 2005, for an alternative account based on the existence of shared "open bigrams" at the letter level). For instance, in the overlap model of position coding (Gómez et al., 2008), the locations of objects (e.g., letters) in a string are distributed along a dimension rather than being fixed. The overlap model also predicts that the amount of perceptual noise at assigning the location of objects decreases with expertise — note that this is consistent with evidence showing that letter transposition effects are greater for beginning readers than for adult skilled readers (see Acha & Perea, 2008; Castles, Davis, Cavalot, & Forster, 2007). Clearly, if object position encoding in a 1D scenario (e.g., visual-word recognition) is noisy, this should be (if anything) amplified in a more complex 2D scenario — as musical notation is. Furthermore, the amount of perceptual uncertainty when encoding the position of the objects in a visual scene should be larger for non-experts (i.e., non-musicians) than for experts (i.e., musicians).

To our knowledge, only a few published papers have examined how note position coding is attained during music reading (Sloboda, 1976, 1978). Sloboda (1976) compared how musicians (i.e., music students) and non-musicians encoded the notes in a simplified staff composed of several dots. In Experiment 1 of Sloboda (1976), a staff composed of one-to-five dots was presented for 20 ms or 2000 ms. The participants' task was to write down the dots in the staff in the appropriate left-to-right order. Sloboda examined the pattern of errors in the vertical axis (i.e., pitch). At the 20-ms duration exposition, the distribution of errors as a function of the distance from the correct responses (in terms of distance in vertical steps [i.e., second intervals], from 0 to 6; 0 = correct) was 41%, 41%, 13%, 5%, 0%, 0%, and 0% for the musicians, and 33%, 35%, 18%, 9%, 5%, 0%, and 0% for the non-musicians, respectively. The parallel effects with the 2000-ms exposure duration followed the same pattern, except that position uncertainty was substantially reduced — in particular for the musicians. Specifically, the distribution of errors as a function of the distance from the correct responses (distance in vertical steps) was 95%, 5%, 0%, 0%, 0%, 0%, and 0% for the musicians, and 57%, 20%, 16%, 4%, 1%, 1%, and 1% for the non-musicians, respectively. Noticeably, at this long exposure duration, the overall number of errors was fewer for musicians than for non-musicians. Sloboda (1976) also examined the error distributions of trials in the simplest condition (i.e., one dot in the staff). At the 20-ms exposure duration condition, the distribution of errors (distance in vertical steps, from 0 to 2; 0 = correct) was 48%, 52%, and 0% for the musicians, and 46%, 53%, and 1% for the non-musicians, respectively. Thus, the data from Sloboda (1976) revealed a pattern consistent with the assumption of perceptual uncertainty in the vertical axis that is dependent on the participant's expertise (i.e., perceptual noise is smaller in the experts [musicians]) – except in the simplest condition.

In a later study, Sloboda (1978) measured how musicians (i.e., music students) and non-musicians encoded positional information about the contour of note sequences. The idea was that, because of their expertise, musicians could use cues on the relative contour of notes that would help them reduce perceptual uncertainty regarding pitch (i.e., the y-axis). In Sloboda's (1978) experiment, participants were presented for 50 ms with two staves composed of four dots, and were asked to reproduce the vertical position of the dots in the correct left-to-right order. Responses were analyzed with four scoring methods: i) exact position (1 = correct vertical position, 0 = otherwise); ii) approximate position (0 = correct vertical position, 1 = displacement of one vertical position, 2 = displacement of two vertical positions, etc.); iii) absolute contour (1 = the rank vertical position of a pair of adjacent dots was kept, 0 = otherwise); and iv) relative contour (1 = the triplet of adjacent dots kept the correct angle, 0 = otherwise). Results revealed that musicians were able to reproduce correctly more dots than non-musicians using an absolute-contour measure (i.e., via pairs of dots), whereas the differences with the other scoring methods showed a similar pattern but they were not significant. Thus, the data from Sloboda (1978) revealed that global encoding of pitch information (i.e., relative contour) is less modulated by expertise than more local measures (i.e., absolute contour).

In the present experiment, we employed a same–different pattern-recognition task to examine note position coding in musicians and non-musicians. Participants were presented with two successive staves composed of four notes and had to decide whether the staves were the same or not. This task allows us to obtain not only a measure of accuracy, but also the response times (see Ratcliff, 1981). Although the present scenario is closer to musical notation than the simple dots employed by Sloboda (1976, 1978), the task is still simple enough so that it can used to compare the data in musicians and non-musicians. Because we focused on the early stages of the encoding of position of the notes and on how this process might be modulated by expertise (i.e., musicians vs. non-musicians), we opted for a brief presentation of the staves. The procedure followed in the experiment mimicked that which was employed by Duñabeitia et al. (2012) — they used strings of four letters, symbols, and digits. The critical contrasts correspond to the "different" trials. For these trials, the difference between the staves was in the y-axis of the internal notes (i.e., pitch), the x-axis of the internal notes (i.e., temporal sequence), and the simultaneous switching of the vertical and horizontal axes corresponding to the internal notes (transposition of two notes; see Fig. 1). These three conditions were tested against the appropriate replacement-note control conditions — these [control] conditions kept the same relative contour as their corresponding probes (see Fig. 1; see also Perea & Lupker, 2003, 2004, for discussion of the appropriate control conditions in transposition experiments).

The rationale behind the present same–different experiment is clear: the more perceptually similar the two staves are, the longer the response times and the higher the error rates. Importantly, in this type of "interference" tasks, error rates may be more sensitive to the experimental manipulations than the response times (e.g., Perea & Lupker, 2004; see also Duñabeitia et al., 2012). For instance, Duñabeitia et al. (2012) found an interference effect (i.e., the difference between the error rates in the replacement [control] condition and the transposition condition) of −7.7, −11.4, and −18.2% for the strings of digits, symbols, and letters, respectively. To examine whether expertise in the encoding of the stimuli qualified the pattern of data, we recruited two groups of participants: a group of musicians (college-age students who had been studying formal music education for at least eight years; i.e., a similar population as that recruited by Sloboda, 1976, 1978) and a group of non-musicians (university students who had not received any formal music education). Models of object/word recognition that assume that "perceptual noise" is not tied to letters but to all kind of objects (e.g., CODE model, overlap model, among others) assume that the note position coding would only be approximate at the x- and the y-axes during the early stages of music reading — in particular in the y-axis (see Mandler & Parker, 1976, for empirical evidence in complex [unorganized] scenes). Furthermore, "position noise" in the staff should be greater for non-experts (i.e., the non-musicians) than for experts. Alternatively, the lack of perceptual noise when processing the musical notes in the staff would suggest that note

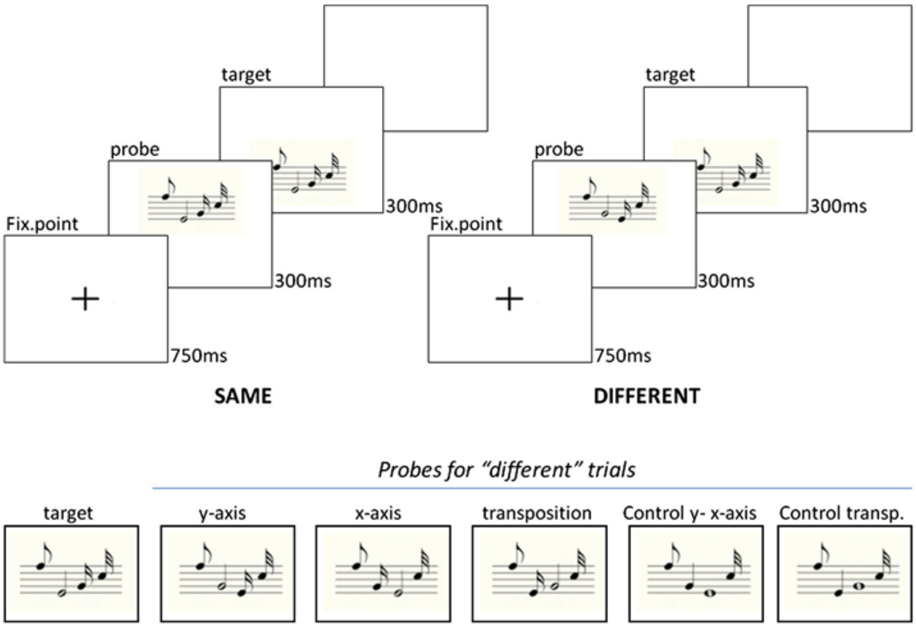

Fig. 1. Schematic description of the same–different task. The panel below specifies the five "different" probe-target conditions. In the y-axis condition, the pitch of the internal notes was switched; in the x-axis condition, the temporal sequence of the internal notes was switched; in the transposition condition, the two internal notes were transposed (in the x- and y-axes); in the control y- and x-axis conditions, the two internal notes were replaced while keeping the same relative contour as in the y- and x-axis conditions; and in the control transposition condition, the two internal notes were replaced while keeping the same relative contour as in the transposition condition.

position coding in musical reading and letter transposition effects in visual-word recognition are qualitatively different. This latter pattern would support the view that letter position effects occur at a "bigram" level specific to letter forms in the "visual word form area" (see Dehaene et al., 2005).

2. Method

2.1. Participants

The musicians were 15 college-aged students recruited in a music school in Valencia, Spain. They had been receiving formal music education for at least eight years. The non-musicians were 15 undergraduate psychology students at the Universitat de València with no formal music training — this was also corroborated by a brief questionnaire on knowledge of music. Participants had normal (or corrected-to-normal) vision and received a small amount of money for their participation (3 €). Four participants (two musicians and two non-musicians) were replaced because they had overall error rates above 40%.

2.2. Materials

The stimuli were 250 probe–target pairs of staves. Each staff was composed of four different notes — all of them with a different pitch and located between the lower/upper horizontal lines in the staff (see Fig. 1). To create the set of stimuli, a computer program generated staves composed of four different notes out of seven notes (from the note 𝅗𝅥 [four beats] to the note 𝅘𝅥𝅯 [a sixteenth beat]). Although the stem of the notes ordinarily goes down on the middle line upwards and goes up on the middle line downwards, we always kept the direction of the stems constant (i.e., upwards) to keep the visual similarity in the staves — note that this is not uncommon in piano notation. The two internal notes always differed by a third interval (e.g., in a C major tonality, if an internal note were C, the other would be E or A). In 125 trials, the probe and the target were the same. In the remaining 125 trials, the probe and the target were "different". For the "different" trials, the target was: 1) the same as the probe except that the pitch (y-axis) of the internal notes was switched; 2) the same as the probe except that the temporal sequence (x-axis) of the internal notes was switched; 3) the same as the probe except for the transposition of the two internal notes (both x-axis and y-axis); 4) the same as conditions 1 and 2 except for the replacement of the two internal notes (control conditions 1&2; note that this control condition kept the same contour as conditions 1 and 2); and 5) the same as condition 3 except for the replacement of the two internal notes (control condition 3; note that this control condition kept the same contour as condition 3). Five lists of stimuli were created for the "different" responses, so that a given target could be preceded by one of the probes in the different conditions in a Latin square manner (i.e., there were 25 trials per condition in each of the "different" conditions). The size of the staff in the computer screen, for both probes and targets, was 11 cm horizontally and 3 cm vertically. The horizontal distance between two consecutive notes was 1.2 cm, and the vertical distance between the internal notes was 0.75 cm.

2.3. Procedure

The experiment took place in a silent room, in groups of one to four. The experiment was conducted using DMDX software (Forster & Forster, 2003). The scheme of a given trial was the following (see Fig. 1). First, a fixation point appeared in the center of the screen for 750 ms. This was followed by the presentation of the probe, 0.3 cm above the fixation point for 300 ms. This was immediately followed by the presentation of the target 0.3 cm below the fixation point for 300 ms — this was the same procedure as in the Duñabeitia et al. (2012) experiment. Participants were instructed to press the "yes" button when the two staves were the same and the "no" button when the two staves were different. They were asked to make their decision as rapidly as possible while trying to be accurate. Fourteen practice trials preceded the 250 experimental trials. The whole session lasted for around 10 min.

3. Results

Incorrect responses and response times that exceeded two standard deviations from the participant's mean were excluded from the response time (RT) analyses. The correct RTs and the error rates in the experimental conditions are displayed in Table 1. Overall, there was a nonsignificant advantage of non-musicians over musicians in the mean RTs (58 ms), $F(1,28) = 2.23$, MSE = 11,831, $p = .146$ [1], whereas non-musicians committed significantly more errors (on average, 9.9%) than the musicians, $F(1,28) = 13.22$, MSE = 41.8, $\eta^2 = .32$, $p = .001$.

For "different" trials, and to examine the critical effects under scrutiny, we conducted planned comparisons on the mean participants' RTs and error rates on the critical conditions vs. their corresponding controls. Specifically, we examined: 1) the effect of position uncertainty in the y-axis (pitch) [condition 1 vs. condition 4]; 2) the effect of position uncertainty in the x-axis (temporal sequence) [condition 2 vs. condition 4], and 3) the effect of note transposition [condition 3 vs. condition 5]. For each contrast, expertise (musicians vs. non-musicians) was also included as a factor in the design.

3.1. Position uncertainty in the y-axis (pitch)

The statistical analyses on the RT data revealed that, on average, participants responded to 100 ms faster when the pitch of the two internal notes had been switched than when the two internal notes (with the same contour) had been replaced, $F(1,28) = 49.87$, MSE = 3041, $\eta^2 = .64$, $p < .001$. This "interference" effect was similar in magnitude for musicians and non-musicians (94 and 108 ms, respectively), as deduced from the lack of interaction between the two factors, $F < 1$.

The statistical analyses on the error data revealed that participants committed more errors when the pitch of the two internal notes had been switched than in its corresponding control condition, $F(1,28) = 81.50$, MSE = 191.5, $\eta^2 = .74$, $p < .001$. This "interference" effect was dramatically greater for the non-musicians than for the musicians (47.4 vs. 17.0%, respectively), as deduced from the interaction between the two factors, $F(1,28) = 18.09$, MSE = 191.6, $\eta^2 = .39$, $p < .001$.

3.2. Position uncertainty in the x-axis (temporal sequence)

The statistical analyses on the RT data failed to reveal a difference between the responses to the staves in which the temporal sequence of the two internal notes had been switched relative to the appropriate replacement-note condition (with the same contour), $F(1,28) = 1.38$, $p > .24$.

The statistical analyses on the error data revealed that participants made more errors when the temporal sequence of the two internal notes had been switched than in the appropriate control condition, $F(1,28) = 16.48$, MSE = 23.3, $\eta^2 = .37$, $p < .001$. The significant interaction between the two factors, $F(1,28) = 8.95$, MSE = 23.3, $\eta^2 = .24$, $p = .006$, reflected that this "interference" effect occurred for the non-musicians (8.8%; $t(14) = 3.55$, $p = .003$), but not for the musicians (1.3%, $t < 1$).

3.3. Effect of note transposition

The statistical analyses on the latency data failed to reveal a difference between the staves in which the two internal notes had been transposed and the appropriate replacement-note control condition (i.e., with the same contour as the transposition condition), $F < 1$. This pattern of data was similar for musicians and non-musicians (interaction: $F(1,28) = 1.61$, $p = .21$).

The error data revealed that participants made more errors on trials that had the two internal notes transposed than on control replacement-note trials, $F(1,28) = 23.00$, MSE = 66.0, $\eta^2 = .45$, $p < .001$. This "interference" effect was similar in magnitude for non-musicians and musicians (9.2 and 11.0%, respectively; interaction: $F < 1$).

Table 1
Response times and error rates (in parenthesis) for each of the experimental conditions in the experiment.

	Different responses							
	Y-axis	X-axis	Transp.	Ctrl (Y, X)	Ctrl (transp.)	Interference effect (vs. control)		
						Y-axis	X-axis	Transp.
Musicians								
TRs	788	708	720	694	723	94	14	−3
% Errors	21.3	5.6	21.9	4.3	10.9	17.0	1.3	11.0
Non-musicians								
TRs	748	644	664	640	645	108	4	19
% Errors	54.9	16.3	22.0	7.5	12.8	47.4	8.8	9.2

Note: The interference effects were computed by subtracting the related conditions vs. the control conditions. For "same" trials, mean RTs and percentage of errors were 702 ms (6.4%) and 637 ms (8.5%) for the musicians and non-musicians, respectively.

4. Discussion

The present experiment examined how note position encoding was attained when reading musical notation in musicians and non-musicians. As indicated in the Introduction, prior research on letter position coding during visual-word recognition and reading (i.e., a 1D scenario) has revealed that: i) letter position coding is not accurate at early stages of processing (i.e., there is perceptual uncertainty concerning a word's letter positions), and ii) the amount of position uncertainty is larger for beginning readers than for skilled readers. Here we demonstrated a similar pattern of perceptual uncertainty in a 2D scenario: music notation (e.g., see Saariluoma, 1994, for position encoding in chess, another 2D scenario). To correctly read musical notation, it is critical to identify not only the temporal duration of each note, but also its pitch (y-axis) and its temporal sequence (x-axis). Results revealed the existence of position uncertainty in the coding of notes along the y- and x-axes while reading musical notation. In addition, the process of note position coding was noisier for non-musicians than for musicians in both axes — the transposition effect was similar in size for musicians and non-musicians, though. We now examine the implications of these findings for music reading and for the categorization of the individual elements in a visual scene.

The data on pitch encoding of musical notes (i.e., y-axis) revealed that participants had difficulty encoding the y-axis of musical notes relative to the control condition. The interference effect in the error rates was dramatically higher for non-musicians than for musicians (47.5 vs. 17.1%, respectively) — as indicated in the Introduction, error rates in this type of paradigms are more sensitive to the effects of interest than response times (e.g., see Perea & Lupker, 2004). This finding extends the Sloboda (1976, 1978) data on perceptual uncertainty of musical notes in the y-axis using a more ecological setting (i.e., using musical notes rather than dots). Furthermore, when the temporal sequence (x-axis) of two internal notes was switched, we found an interference effect relative to the appropriate control in the error data for non-musicians (8.8%). This effect was absent for the musicians. Thus, in the x-axis, there is also a larger degree of perceptual uncertainty when processing the musical notes for an unskilled "music perception" system than in a skilled "music perception" system. Clearly, the data

[1] One reason why non-musicians are (numerically) faster than musicians is that the non-musicians in the experiment were psychology undergraduates who, in some cases, had taken part in previous response time experiments.

from the single changes in the y- and the x-axes are consistent with the idea that non-experts present more perceptual uncertainty when encoding the position of objects, in a similar way to what happens in visual-word recognition with developing readers (Acha & Perea, 2008; Castles et al., 2007). Although note position coding was noisier in the y-axis than in the x-axis (see also Mandler & Parker, 1976, for a similar pattern when processing visual scenes), one must be cautious at interpreting this finding. The reason is that, in musical notation, the horizontal spacing between two consecutive notes (i.e., x-axis) is larger than the vertical spacing (i.e., y-axis) between the same notes differing by a third interval — which was the manipulation in the present experiment (see Perea & Gómez, 2012, for evidence of an effect of inter-letter spacing in visual-word recognition). Thus, a more extreme manipulation of the vertical spacing (i.e., similar in size to the horizontal spacing) would be necessary to establish firm conclusions regarding the position uncertainty along the horizontal vs. vertical axes. Furthermore, as an anonymous reviewer pointed out, the lines from the staff may introduce some extra perceptual noise due to crowding-like effects, thus making the position coding of the notes in the y-axis more difficult for non-musicians than for musicians.

Importantly, and as in the Sloboda (1976, 1978) experiments, there were instances in which note position coding was not modulated by expertise. To fully understand how expertise affects note position encoding, it is important to know not only when a given effect is modulated by expertise, but also when a given effect is not qualified by expertise (i.e., when invariances occur). When the changes in the staff involved the transposition of the two internal notes, we found an overall interference effect in the error rates (around 10%) that was not modulated by expertise. A potential (admittedly post hoc) explanation is the following. The lack of an interaction between note transpositions and expertise strongly suggests that the mechanisms at work in the transposition of notes are core (general) cognitive processes that do not depend on (task-specific) expertise in reading musical notation. To explain this result, it may be important to indicate that in the conditions with a single change in the x- or y-axes, the relative contour between probes and targets was always different. Because of their expertise, musicians may employ some specific chunking mechanisms when encoding the notes in the staff (e.g., see Sloboda, 1978) and this would give the musicians an advantage over non-musicians at detecting changes in the overall contour. Critically, this chunking mechanism cannot be at work in the transposition/replacement conditions because the global contour of probes and targets were always the same (see Fig. 1). Under these conditions, the underlying cognitive processes at work may be more related to more general encoding mechanisms in memory tasks (e.g., see Estes, 1975; Ratcliff, 1981, for evidence in letter identification) rather than in fine-grained, expertise-dependent perceptual encoding. Clearly, further research using more ecological settings is necessary to examine in detail the conditions in which expertise modulates note position coding using different techniques (e.g., the monitoring of the participants' eye movements; see Drai-Zerbib, Bigand, & Baccino, 2012; Pollatsek & Rayner, 1990; Waters, Underwood, & Findlay, 1997).

What are the implications of these findings outside musical notation? The present experiment is a demonstration that the position encoding of musical notes in the staff is only approximate, thus providing support for those models that assume that there is perceptual uncertainty when processing the identity and position of a series of objects in a visual scene regardless of the specific nature of the object (musical notes, letters, digits, etc.). Therefore, the present data raise some parsimony issues for those models that assume that letter transposition effects in visual-word recognition arise at a letter level in the "visual word form area" (e.g., Dehaene et al., 2005) — note however that the present data cannot be used to rule out the existence of "bigram" detectors in the visual word form area since brain systems may be duplicated (e.g., see Duñabeitia et al., 2012).

The present experiment may have had some limitations. To determine the existence of perceptual uncertainty along the y- and x-axes during music reading, the staff was simplified to a series of four randomly generated notes (i.e., clefs, time/key signatures, accidentals, etc. were not presented). We did so to effectively compare note position coding in musicians and non-musicians — it is important to stress here that the (initial) underlying processes to object position coding (as measured by masked priming) may be similar for quite different objects (see Muñoz et al., 2012). In addition, we acknowledge that top-down processes may influence note position coding during music reading — in a similar way that letter position coding is more precise for transposed-letter words than for transposed-letter pseudowords (e.g., Duñabeitia, Perea, & Carreiras, 2009; Gómez et al., 2008).

To sum up, the present experiment has provided evidence of perceptual uncertainty during music reading. The present data are consistent with models of visual attention that assume that object position coding is only approximate at the early stages of processing and that this process is dependent on expertise. Further experimentation should be conducted to examine the subtleties of note position encoding in highly skilled musicians using more ecological settings.

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