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## Music Perception: Sounds Lost in Space

A recent study of spatial processing in amusia makes a controversial claim that such musical deficits may be understood in terms of a problem in the representation of space. If such a link is demonstrated to be causal, it would challenge the prevailing view that deficits in amusia are specific to the musical or even the auditory domain.

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Individuals with amusia report life-long difficulties in making sense of music, even though their hearing and other cognitive faculties are normal. They cannot recognize tunes that would be familiar to others from their culture; they fail to sing in tune; and, to them, one song sounds very much like another. For some people with this condition, music is highly aversive. One described Rachmaninov's second piano concerto as sounding like 'banging and noise', while another admitted she avoided social occasions involving music 'at all costs' [1].

While a body of research has converged in pinpointing fine-grained pitch perception as the cause of the deficit, a recent study [2] has proposed an association between amusia and spatial deficits. These researchers identified a group of amusic individuals using a subtest from the Montreal Battery for the Evaluation of Amusia (MBEA) [3]. This battery is a series of tests in which participants indicate whether a pair of tunes is exactly the same or slightly different. In the 'contour' subtest used by Douglas and Bilkey [2], the difference, when it occurred, involved a change in one of the notes of the second tune such that the pattern of ups and downs was different for each tune — a very salient change for most people.

Douglas and Bilkey's [2] amusic group made incorrect responses for eight or more trials out of 30, putting their performance in the bottom 2.5% of a normative sample [3]. The amusics were compared to control subjects on a classic mental rotation task which required them to report whether pairs of line drawings represented the same three-dimensional object from a different viewpoint, or a different three-dimensional object altogether. Compared with the control subjects, who scored in the normal range on the MBEA, the amusics made significantly more errors, even when matched for musical training background. Furthermore, within the amusic group, there was a positive correlation between mental rotation score and performance on the MBEA contour subtest. Although the two groups were not balanced for gender (there were more females in the amusic group), this relationship between the musical score and the spatial score still held when gender was partialled out.

Two further experiments are presented to bolster the claim that amusia is associated with deficits in spatial processing. Douglas and Bilkey [2] used a Stimulus Response Compatibility Task (SRC), in which participants compared the pitches of two tones and indicated whether the second was higher or lower, using a response configuration that was

either 'compatible' ('higher' and 'lower' responses mapped to responses that are higher and lower in vertical space) or 'incompatible' (the reverse). A similar task has been previously used by Rusconi *et al.* [4] and Lidji *et al.* [5] to demonstrate that pitch is mapped onto a vertical representation, even when the task does not explicitly concern pitch. Control participants made more errors for the incompatible configuration, while the amusics made equivalent numbers of errors for both configurations.

While at first sight this may seem to support the claim that amusics are failing to implement a spatial representation of pitch, it seems that the amusics were worse at discriminating pitch direction overall, with twice as many errors as controls. Foxton *et al.* [6] have reported that amusics, as a group, have thresholds for pitch direction discrimination that exceed two semitones (the difference between Do and Re in 'Do-Re-Mi'). The issue here is that Douglas and Bilkey's [2] inclusion of such a small interval does not allow for disambiguation of a deficit in simple perception of pitch direction from a deficit in the mapping of pitch onto vertical space.

These potential limitations notwithstanding, the findings concerning mental rotation performance resonate with other studies of amusia and pitch representation. Links between visuo-spatial performance and musical expertise have previously been drawn, variously highlighting superior performance of musicians on visuospatial tasks [7,8], the activation of brain areas associated with spatial processing such as superior parietal cortex during musical perception [9–11], and changes in the structure of superior parietal cortex and other regions associated with

visuo-spatial processing [12]. However, such findings have generally been attributed to musicians' expertise in making spatial sensori-motor transformations — the rapid conversion from spatially organized symbols on the staff to the instrument-specific fingerings that must occur during music reading and performance.

The closest suggestion for a link between spatial abilities and musical listening in musically untrained individuals comes from a paper by Cupchik *et al.* [13] who demonstrated a correlation between performance on a mental rotation task and the ability of the listener to detect when a musical tune had been played backwards. Similar to the mental rotation task, this musical permutation involves explicitly transforming the representation of a sensory stimulus from one co-ordinate frame to another. There is a sense in which musical listening, even without such explicit demands, involves keeping track of musical events as they are transposed or transformed — a fusion of the familiar and the unexpected [14]. The extent to which the co-ordinate systems involved in making visual transformations are independent or interact with the co-ordinate systems involved in auditory transformations is an important question which remains to be elucidated.

Although Douglas and Bilkey [2] argue that differences in spatial ability may affect the extent to which music can be perceived, the reverse argument can also be made: that is, the amount of time spent engaged in active musical listening may contribute to shaping spatial processing in general. The authors report that both amusic and control subjects claimed to listen to an equal amount of music, yet this seems surprising given a recent study [1] which found that amusics reported, on average, listening to music of their own choice for three hours a week compared to nine hours in a matched control group. It therefore seems possible that the amusic and control groups in Douglas and Bilkey's [2] study were not equated for the amount of time spent listening to music of their own

choice, as opposed to music that they are incidentally exposed to, for instance in public places [15]. The view that the musical listening process is an active one, involving listeners consciously and deliberately using music to achieve or enhance certain, predominantly affective states [16], underlines the importance of making this distinction explicit. Of course, it is also possible that even if the amount of active musical listening were similar in amusic and control participants, music perceptual deficits may limit the capacity for processing the higher order structure of music.

These two opposing hypotheses concerning the directionality of the association between musical and spatial ability can be tested: if active musical listening impacts upon spatial ability, the extent of active musical listening should predict spatial ability but not *vice versa*. On the other hand, if spatial ability underlies musical perception, performance on tasks like mental rotation should predict the score on a test such as the MBEA but not *vice versa*. Nature's experiments [1] — neurological injury due to stroke — already provide a test of the latter. Brain injury to the parietal cortex severely limits visuo-spatial perception, in the form of visual-neglect syndrome. To the best of our knowledge the literature does not include reports of musical deficiency in visual neglect syndrome, although lesion-based investigations of pitch ability in these patients are lacking.

The suggestion of Douglas and Bilkey [2] that music perception may depend on the same cognitive mechanisms that are required to process space may cause discord within the scientific community. Although it encourages us to look at amusia from a different perspective, there is a clear need for replication and extension before such a view is accepted. In particular it will be important to establish that differences in spatial representation (as suggested for the SRC task) are independent of differences in simple pitch perception and to determine whether the deficits in spatial ability emerge from or result in the deficits seen in musical perception.

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