When high pitches sound low: Children’s acquisition of space-pitch metaphors

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Abstract

Some languages describe musical pitch in terms of spatial height; others in terms of thickness. Differences in pitch metaphors also shape adults’ nonlinguistic space-pitch representations. At the same time, 4-month-old infants have both types of space-pitch mappings available. This tension between prelinguistic space-pitch associations and their subsequent linguistic mediation raises questions about the acquisition of space-pitch metaphors. To address this issue, 5-year-old Dutch children were tested on their linguistic knowledge of pitch metaphors, and nonlinguistic space-pitch associations. Our results suggest 5-year-olds understand height-pitch metaphors in a reversed fashion (high pitch = *low*). Children displayed good comprehension of a thickness-pitch metaphor, despite its absence in Dutch. In nonlinguistic tasks, however, children did not show consistent space-pitch associations. Overall, pitch representations do not seem to be influenced by linguistic metaphors in 5-year-olds, suggesting that effects of language on musical pitch arise rather late during development.

Keywords: pitch, space, metaphor, linguistic relativity, language acquisition

Introduction

In many languages people talk about musical pitch metaphorically, in terms of space. In English, for instance, tones can be described as ‘high’ or ‘low’, and in German or Dutch the term ‘pitch’ itself is actually a height-metaphor (*Tonhöhe*, *toonhoogte*, ‘tonal height’ = ‘pitch’). Other languages employ alternative spatial source-domains. The Manza of Central Africa, for instance, express pitch in terms of size, with high pitches being referred to as ‘small’ and low pitches as ‘large’ (Stone, 1981). Languages like Farsi, Turkish, and Zapotec, on the other hand, describe musical pitch in terms of thickness, with high pitches described as ‘thin’ and low pitches as ‘thick’ (Shayan, Ozturk, & Sicoli, 2011).

Differences in linguistic pitch metaphors also seem to affect nonlinguistic space-pitch associations (Dolscheid, Shayan, Majid & Casasanto, 2013). Dutch speakers (who, like English speakers, use a height-pitch metaphor) and Farsi speakers (who use a thickness-pitch metaphor) were asked to sing back musical pitches they heard in the presence of irrelevant spatial information (i.e. lines that varied either in height or in thickness). Dutch speakers’ pitch reproduction was significantly influenced by spatial height (but not thickness), but the reverse was true for speakers of Farsi. These findings suggest language can influence nonlinguistic cognition, lending support to the principle of linguistic relativity (Whorf, 1956).

Although language shapes links between space and musical pitch, it does not establish these mappings in the first place. Even infants without language possess implicit space-pitch associations (e.g. Dolscheid, Hunnius, Casasanto, & Majid, 2014; Jeschonek, Pauen & Babocsai, 2012; Walker et al., 2010). Four-month-old Dutch infants, for instance, are sensitive to height-pitch as well as thickness-pitch mappings, suggesting both associations are present prelinguistically (Dolscheid, et al., 2014).

How can these findings be reconciled? On one proposal, metaphors in language may gradually affect nonlinguistic space-pitch associations via associative learning (e.g. Casasanto, 2008). Repeated use of a particular linguistic space-pitch metaphor may – over time – strengthen one mapping over the other, resulting in language-specific differences in adults. Support for this associative learning account comes from a training study. After being trained to use Farsi-like metaphors describing pitch relationships in terms of thickness, Dutch speakers’ nonlinguistic thickness-pitch mappings also resembled those of Farsi speakers (Dolscheid et al., 2013). While this training study demonstrates how language may affect space-pitch associations in principle, it does not consider first language acquisition. How do children acquire linguistic space-pitch metaphors? And when do these metaphors start to impinge on nonlinguistic space-pitch associations?

Linguistic relativity in development

Effects of language on cognition differ by domain (Wolff & Holmes, 2011), and over development. Some effects arise much earlier than others. For spatial relations (e.g., ‘in’ or ‘on’), children show some language-specific effects on cognition as early as 2-years (Choi, 2006). Other linguistic relativity effects develop later. For instance, cross-linguistic differences in mass/count distinctions that affect classification preferences (e.g. between English and Yucatec Maya) do not arise until 9-years (Lucy & Gaskins, 2001).

For musical pitch, some first evidence suggests language-specific mappings may already be present in 2- to 5-year-old children (Shayan, Ozturk, Bowerman & Majid, 2014). Farsi and Turkish speaking children successfully associated spatial thickness and pitch in a similarity-matching task, whereas same-aged German children (who do not have a thickness metaphor in their language) did not (Shayan et al., 2014). While Shayan and colleagues shed some light on the development of thickness-pitch mappings, they do not test the development of height-pitch associations. Focusing on just one type of space-pitch mappings leaves open how different space-pitch associations interact during acquisition. To address these issues, we tested children's nonlinguistic mappings in both height-pitch and thickness-pitch matching tasks (Experiment 2). As a prerequisite for the non-linguistic study, we first examined children's linguistic mastery of space-pitch metaphors (Experiment 1).

Acquisition of linguistic space-pitch metaphors

There is evidence height-pitch metaphors are acquired late during language development (e.g., Costa-Giomi & Descombes, 1996). Three- to 6-year old children have difficulties in both pitch metaphor production (e.g. Webster & Schlentrich, 1982) and comprehension (Durkin & Townsend, 1997). One reason for these difficulties could be the polysemous nature of the terms: they describe both spatial height and musical pitch. In support of this, French speaking children improved in labeling musical tones when trained to describe them as *aigu* and *grave* (a pair of antonyms exclusively used to label pitch) compared to training with the metaphoric expressions *haut* 'high' and *bas* 'low' (Costa-Giomi & Descombes, 1996). This explanation, however, does not fit the thickness-pitch metaphor acquisition data. Despite similar polysemy (*thick* is used for both spatial thickness and pitch), 2- to 5-year-old Farsi and Turkish children showed no difficulties in pitch metaphor comprehension (Shayan et al., 2014).

To examine this in more detail, we focus on comprehension of both height-pitch and thickness-pitch terminology in 5-year-old Dutch-speaking children (Experiment 1). Since adult speakers of Dutch encode musical pitch in terms of height, but not thickness, one may predict that Dutch children know linguistic height-pitch metaphors but not thickness-pitch metaphors. If so, 5-year-old children should comprehend height-pitch metaphors better than thickness-pitch metaphors. Alternatively, since height-pitch metaphors appear to be acquired rather late (compared to thickness-pitch metaphors), we might not see language-specific patterns in this age-group.

The investigation of space-pitch metaphor acquisition further touches on issues of markedness. As has often been noted, children acquire unmarked expressions before they acquire marked ones (e.g. Clark, 1972). The unmarked endpoint is usually defined as the default, more frequent or broader dimension as opposed to the marked one (see e.g., Clark, 1973; Proctor & Cho, 2006). Space-pitch metaphors, too, can be described as being bipolar, consisting of an unmarked endpoint (high, thick), and an opposing marked endpoint (low, thin). Unlike 'height' which can refer to a whole dimension, *'lowness' (marked) cannot be used in this way. In the same vein, 'thickness' represents the (default) unmarked spatial dimension, whereas * 'thinness' represents the marked one. Previous research shows children understand unmarked spatial and spatio-temporal terms better than marked ones (e.g. Clark, 1972), but it is not clear this also applies to sound meanings. Testing children's comprehension of space-pitch metaphors allows us to assess whether the same asynchrony exists for pitch. This question is of particular interest given the markedness relationship between space and pitch reverses in height and thickness metaphors. While high and thick both constitute unmarked ends of the spatial dimensions, higher tonal frequency is described by the unmarked *high* in height-pitch metaphors, but encoded with the marked endpoint *thin* in thickness-pitch metaphors (see also Shayan et al., 2014).

Overall, the goal of Experiment 1 was to assess children's comprehension of linguistic space-pitch metaphors including patterns of markedness.[1]

Experiment 1

Methods

Participants

Five-year-old Dutch children (*N*=21) participated in the study (12 male; mean age: 5.1, range: 5.0–5.3). Children were recruited by the Baby Research Center Nijmegen (BRC) and compensated for participation with money or a small gift. According to a musical background questionnaire filled in by parents, no child had received musical training. Children played no instruments and were not familiar with note reading traditions.

Materials and Procedure

Children sat in front of a 20" computer monitor, next to the experimenter. All stimuli were presented on a Windows computer using Presentation software (version 14.9., www.neurobs.com). Children wore child-sized shielded headphones. Videos of two squares (*vierkante vriendjes*, 'square friends') were presented on a computer screen. During each trial, the left square 'sang' a single tone for two seconds followed by the right square 'singing' a single tone for two seconds. For the duration of the tone, the target square wiggled to indicate it was producing the sound. Three different tone pairs (262hz vs. 698hz, 262hz vs. 523hz, 330hz vs. 523hz) were presented four times. Half the trials started with a high pitch; half with a low pitch. In total, there were twelve trials. In the height-pitch condition, children were asked: *Welke zingt hoog/laag?* (Which one sings high/low?) The same number of marked (low) and unmarked (high) questions was presented, order counterbalanced. Questions were read out aloud by the experimenter. The thickness-pitch condition followed the same procedure, and was always presented last. The

[1] To avoid spill-over effects from linguistic to nonlinguistic tasks, Experiment 1 was administered after Experiment 2, but for reasons of logical coherence, Experiment 1 is reported first.

questions were: *Welke zingt dik/dun?* (Which one sings thick/thin?) Each child was tested in both the height-pitch and thickness-pitch conditions. For each trial, children were asked to point to the appropriate square. If they were not sure, they could ask to hear the sounds again and the whole trial was repeated. Responses were evaluated as correct when they followed Dutch height-pitch and Farsi thickness-pitch metaphors (i.e., thin=high pitch; thick=low pitch).[2]

Results

The mean proportion of correct responses on the pitch comprehension tasks was calculated separately for height-pitch and thickness-pitch. For height-pitch, children's mean proportion of correct responses was significantly below chance (M=.33) $t(20)=2.52$, $p=.02$, $d=.55$.[3] In the thickness-pitch comprehension task, mean proportion of correct responses was significantly above chance (M=.71) $t(20)=4.13$, $p=.001$, $d=.90$.

A repeated-measures ANOVA with factors metaphor type (height vs. thickness) and markedness (unmarked [high, thick] vs. marked [low, thin]) was conducted. Mean proportion of correct responses served as the dependent variable. There was a significant main effect of metaphor $F(1,20)=4.71$, $p=.04$, $\eta_p^2=.43$ and markedness $F(1,20)=15.00$, $p=.001$, $\eta_p^2=.46$, but no significant interaction $F(1,20)=.06$, *ns,* $\eta_p^2=.003$. Simple contrasts revealed better performance in thickness-pitch than height-pitch comprehension $F(1,20)=4.71$, $p=.04$, $\eta_p^2=.43$. Moreover, unmarked questions elicited better performance than marked questions $F(1,20)=15.00$, $p=.001$, $\eta_p^2=.46$.

Discussion

We found that 5-year-old Dutch children understand thickness-pitch mappings better than height-pitch mappings. In fact, children seemed to favor a reverse height-pitch mapping, with 'high' referring to low-pitched sounds and 'low' referring to high-pitched sounds. Given Dutch has a height-pitch metaphor, this finding is unexpected. The results also confirmed an effect of markedness in pitch metaphor comprehension. Children seem to understand unmarked pitch terms (Which one sounds high/thick) better than marked terms (low/thin). Fuller discussion of the results will follow in the General Discussion.

Experiment 2

In order to explore possible effects of language on thought, the same 5-year-old children tested in Experiment 1 were also tested in a non-linguistic height-pitch and thickness-pitch matching condition (adapted from Dolscheid et al., 2014). To ensure that the space-pitch task was in principle sensitive to language-specific mappings, we also tested adult participants in both conditions.

Since 5-year-old children's linguistic space-pitch metaphors appear to be different from those of adults, children's performance on the nonlinguistic task was expected to be different as well. Dutch adults are assumed to display a height-pitch association, but not a thickness-pitch association in line with metaphors in language. The reverse could be predicted for 5-year-old children. Consistent with their linguistic behavior in Experiment 1, it is possible children map high pitch to low space. In order to link children's linguistic and nonlinguistic space-pitch associations, their performance on the linguistic pitch comprehension task (Experiment 1) was used as a predictor for their nonlinguistic performance. If language mediates pitch associations already in 5-year-olds, an effect of linguistic pitch comprehension on nonlinguistic space-pitch mappings is expected.

Methods

Participants

In addition to the Dutch children (N=21), adult native speakers of Dutch (N=7) were tested on the nonlinguistic space-pitch matching tasks (and served as a pilot for the procedure).

Materials and Procedure

Pretest To ensure children (and adults) understood the main task, a pretest was conducted (for a similar test see Mondloch & Maurer, 2004). Participants wore shielded headphones and were presented with two competing exemplars on a computer screen. These could be stationary or moving objects or animals (e.g. images of a horse and a cow). At the same time a sound corresponding to one of the exemplars was presented via headphones (e.g. horse neighing). Participants were asked to indicate which object/animal 'belonged' to the sound they heard by pressing the corresponding button on a button-box. The pretest consisted of 4 trials. Only participants who responded correctly on 3 or more trials were tested in the space-pitch association tasks. All children (and adults) fulfilled this criterion.

Space-pitch matching tasks Once participants passed the pretest criterion, they were presented with the test trials. In the height-pitch condition, two orange bouncing balls (approximately 2.5 cm diameter) were presented side by side in front of a 20 x 20 cm grid of small, white dots on a black field (see Figure 1, panel a). Both balls followed the same trajectory, however, they started moving from different positions in space: one started from the top, the other from the bottom (i.e. at the two extremes of the vertical trajectory). Animations were accompanied by the sound of a sliding whistle (a sinusoidal tone). The fundamental frequency of the sound changed at a constant

[2] To ensure children were able to comprehend height and thickness terminology in a non-metaphorical spatial sense, an additional space comprehension task was administered. All children performed correctly on all height and thickness trials, demonstrating comprehension of basic spatial terminology.

[3] According to Kolmogorov-Smirnov-tests, the assumption of normally distributed data was not met (all p-values < .05). Therefore additional non-parametric analyses were performed confirming the results of the parametric tests.

rate, between 300 and 1700 Hz over 2.5 s, coinciding with a single phase of the animation (e.g., ball moving up). The pitch movement thus coincided with movement of both balls, but only one movement direction. The amplitude of the sound increased and then decreased between approximately 47 and 84 dB within each phase of the animation, peaking at 1000 Hz. Participants were presented with 8 trials in which they had to match the animation and sound by pressing the corresponding button. Correct response side (right vs. left) was counterbalanced within participants.

A trial lasted for 30 seconds and was stopped as soon as a button was pressed. If no decision was made during these 30 seconds, participants were asked to choose the correct animation afterward. Responses were considered correct when they were in line with the Dutch height-pitch metaphor (i.e. when the ball's rising movement corresponded to rising pitch).

The thickness-pitch condition had the same procedure and trial structure. However, instead of bouncing balls, two vertical tubes were presented expanding in spatial thickness (see Figure 1, panel b). Eight thickness-pitch trials were presented. Responses were considered correct when they were in line with a Farsi-like thickness-pitch metaphor (i.e. when the expanding tube was matched to the sound whose fundamental frequency 'fell').

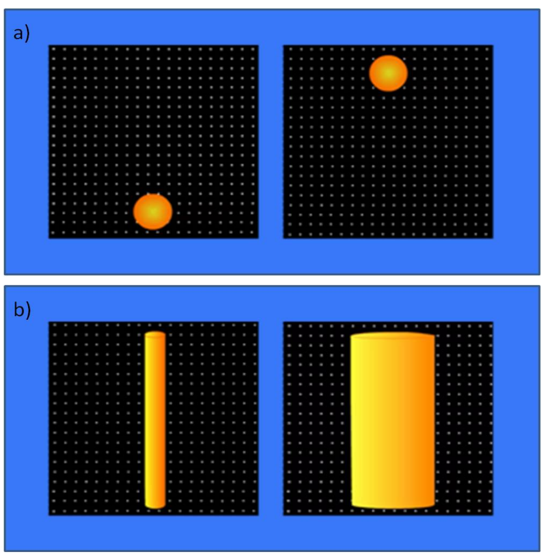

Figure 1: Examples of the test trials. Panel a) In the height-pitch matching condition, participants were presented with two videos with bouncing balls. Panel b) In the thickness-pitch matching condition, stimuli consisted of tubes changing from thin to thick and vice versa.

Results

Adults

Adult participants' mean proportions of correct responses were above chance in the height-pitch condition, corresponding to the Dutch height-pitch metaphor ($M = .82$) $t(6)=3.58$, $p=.01$, $d=1.35$. Performance on the thickness pitch trials, however, was at chance ($M = .38$) $t(6)=.1.55$, *ns,* $d=.59$. A paired-samples t-test showed significantly better performance on height-pitch trials than thickness-pitch trials $t(6)=3.64$, $p=.01$, $d=1{,}38$.

Five-year-old children

Children performed at chance in both height-pitch ($M=.58$), $t(20)=1.64$, *ns,* $d=.36$ and thickness-pitch trials ($M=.52$), $t(20)=.44$, *ns,* $d=.10$. Given the results of the linguistic pitch comprehension task (Experiment 1), one might expect to see differences in performance in non-linguistic conditions. However, a paired-sample t-test revealed no significant difference between height-pitch and thickness-pitch associations, $t(20)=.63$, *ns,* $d=.14$.

To assess whether performance on the pitch elicitation task in Experiment 1 predicted patterns in nonlinguistic space-pitch associations, simple regression analyses were conducted. Mean proportion of correct responses on the height-pitch comprehension condition were entered as a regressor to predict performance (mean proportion correct) on the nonlinguistic height-pitch matching condition. The same analysis was performed for linguistic and nonlinguistic thickness-pitch mappings. There was no significant effect of height-pitch metaphor comprehension on nonlinguistic height-pitch matching performance $b=-.12$, $F(1,19)=.69$, *ns,* $r^2=.04$. There was also no significant effect of thickness-pitch metaphor comprehension on the corresponding nonlinguistic condition, $b=-.26$, $F(1,19)=1.3$, *ns,* $r^2=.06$. Finally, children were assigned to two different groups in the height-pitch comprehension condition, those performing at chance or below ($n=16$) and those performing above chance ($n=5$). An independent t-test between groups revealed performance in the linguistic height-pitch condition had no significant effect on nonlinguistic height-pitch associations either (i.e., groups did not differ with regard to nonlinguistic space-pitch associations) $t(19)=.27$, *ns,* $d=.15$. Likewise, children were assigned to two groups in the thickness-pitch comprehension condition, with children performing at chance or below ($n=7$) and children performing above chance ($n=14$). Performance in thickness-pitch comprehension did not influence nonlinguistic thickness-pitch associations either $t(19)=.38$, *ns,* $d=.18$.

Discussion

Unlike adults whose nonlinguistic space-pitch mappings follow metaphors in language, 5-year-old children performed at chance in both height-pitch and thickness-pitch mapping conditions. Moreover, language did not predict performance on the space-pitch association tasks. So, children do not seem to represent these associations at 5-years.

General Discussion

Language and space-pitch associations follow a more complex relationship than previously thought. Dutch children did not show knowledge of the height-pitch metaphor in their language, in fact they reversed it. This was despite their adult-like comprehension of the spatial source domain (i.e. height). Moreover, children showed better performance for a thickness-pitch metaphor, despite its absence in the Dutch language.

It is possible this is the result of the experimental set-up. To prevent potential confusion, we opted to have a fixed order of testing with thickness-pitch metaphors always at the end of the experiment. Prior assessment of height-pitch comprehension may have served as a training in which children became familiar with the task. But, note, a simple training effect is unlikely to account for the observed pattern (i.e. it cannot explain the reversal of height-pitch metaphors). In order to rule out training effects entirely, one would have to counterbalance the order of height-pitch and thickness-pitch comprehension tasks in the future.

If we take children's better performance in thickness-pitch comprehension at face-value though, we are in need of an explanation for this rather surprising finding. Why do Dutch children understand thickness-pitch but not height-pitch metaphors (and even reverse them)?

The finding that 5-year-olds have difficulties in understanding height-pitch metaphors is not entirely new (see e.g. Costa-Giomi & Descombes, 1996; Durkin & Townsend, 1997). In contrast, numerous studies show non-linguistic associations between spatial height and pitch are already present in prelinguistic infants (Dolscheid et al., 2014; Jeschonek et al., 2012; Walker et al., 2010). There is thus a discrepancy between the early presence of cross-modal height-pitch associations and the difficulty in understanding height-pitch metaphors later. It seems then language "may initially even hinder mappings previously acquired nonverbally" (Eitan, Ornoy, & Gronot, 2012, p. 34). For Dutch children, linguistic height-pitch metaphors require a mapping between established associations and new verbal information, a process which may not be fully complete at the age of five. This may also explain why there is better performance in thickness-pitch metaphor comprehension. The absence of a thickness-pitch metaphor in the Dutch language could leave thickness-pitch associations 'untouched'. An alternative explanation could be the thickness-pitch metaphor is simply more intuitive for children since it follows correspondences in the real world (see e.g. Lewkowicz, 2011). Children may well have experienced people or animals with bigger ('thicker') bodies tend to have lower voices (see also Dolscheid et al., 2014). This account could also explain why Farsi and Turkish children do not show delays in thickness-pitch metaphor comprehension (Shayan et al., 2014).

It is interesting that Dutch children understood height-pitch mappings in a reversed way, with *high* referring to low pitch and *low* referring to high pitch. How does this reversed preference in height-pitch comprehension come about? While this finding appears to be at odds with metaphors used in Dutch or English, other languages make use of a reversed height-pitch mapping: Speakers of the Austronesian language 'Are'are, for instance, talk about high pitch in terms of 'low' or 'down' (Zemp & Malkus, 1979). Although this observation suggests it is not inconceivable to reverse linguistic height-pitch metaphors, it does not explain the Dutch children's pitch comprehension.

Another explanation could lie in the misalignment of Dutch space-pitch terms and their pitch quality. Contrary to sound-symbolic intuitions, the vowel [a] in *laag* ('low') is characterized by higher formant frequencies compared to [o] in *hoog* ('high'). So children may have based their pitch judgments on the terms' pitch information (i.e., frequency of formants) rather than on the terms' meanings. Note however, that the same holds for Dutch thickness terminology but children did not reverse thickness-pitch terms: the vowel [i] in *dik* (thick = low pitch) is higher than [y] in *dun* (thin = high pitch).

A final explanation for Dutch children's height-pitch reversal lies in markedness. Our results show that children are sensitive to markedness patterns in the domain of musical pitch, in analogy to findings in the spatial domain (e.g. Clark, 1972). Children displayed better comprehension of unmarked questions ('Which one sings high/thick?') than marked questions ('Which one sings low/thin?'). There is an interesting difference, however. For space markedness patterns are aligned (i.e., *high*, *thick*, *big*, etc., are all unmarked and refer to bigger entities). The same does not hold for pitch metaphors. Instead, markedness reverses in height- and thickness-pitch metaphors. Children may nevertheless be inclined to use consistent markedness alignment and consider low pitch as the unmarked pole by assigning it with the labels 'high' or 'thick'. The markedness distribution of musical pitch thus appears to differ between 5-year-olds and adult speakers of Dutch, which could also explain children's better performance in thickness-pitch comprehension (low pitch = unmarked = high = thick). Overall, these findings show the acquisition of space-pitch metaphors is a complex and dynamic process, which in turn has implications for linguistic relativity.

While language affects nonlinguistic pitch representations in adults, the results are not conclusive in 5-year-olds. This lack of clarity is partly due to children's unexpected linguistic patterns observed in this study. Based on their linguistic metaphor comprehension, one might have expected better performance on the nonlinguistic thickness-pitch task or even a reversed association in the nonlinguistic height-pitch task. However, this was not the case. Children performed at chance on both nonlinguistic space-pitch tasks. This finding could be for a number of reasons. (A) It could be children (no longer) display consistent space-pitch associations. (B) The matching tasks were simply too difficult for them. These two options are hard to disentangle. However, there are some hints indicating (B) may be correct. While children basically understood the task instructions as illustrated by their correct performance on the pretest (matching sounds to animals or objects), the space-pitch association tasks were more challenging. Children had to keep track of opposing trajectories as well as changing pitch glides which may have been too cognitively demanding.

In general, task difficulty seems to be a critical factor when it comes to children's abilities with cross-modal associations. Marks, Hammeal, and Bornstein (1987), for instance, report that children are unable to systematically map size (big vs. small) to pitch until they are 13 years old. However, others find evidence for size-pitch congruency effects in children as young as three years of age (Mondloch & Maurer, 2004). The lack of nonlinguistic space-pitch mappings in our task is thus not by itself conclusive. Other tasks have to be used in order to distinguish between task difficulty and real absence of space-pitch associations in 5-year-olds.

For the moment it seems unlikely language affects children's nonlinguistic space-pitch associations in the same way it does in adults (see Dolscheid et al., 2013; see also adult data in Experiment 2). Consequently linguistic relativity effects in the domain of musical pitch might be classified as rather late compared to other effects (e.g. Choi, 2006). Testing older children is thus a necessary next step and could reveal when linguistic metaphors become more adult-like and at what age they start to affect nonlinguistic behavior in the domain of musical pitch.

Conclusions

Five-year-old children showed sensitivity to markedness patterns in pitch metaphors. Children found it easier to comprehend unmarked space-pitch metaphors in comparison to marked associations, suggesting markedness understanding holds for pitch, as well as space. Contrary to predictions based on language input, 5-year-old Dutch children displayed better comprehension for thickness-pitch metaphors than height-pitch metaphors. Children even reversed the latter. Thus, at 5-years, children do not yet show patterns of comprehension compatible with their language input. Similarly, effects of language on nonlinguistic cognition do not appear to be present in 5-year-olds. Together, these findings suggest linguistic relativity effects in the domain of musical pitch arise rather late during development.

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