Laterality: Asymmetries of Body, Brain and Cognition
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/plat20

Children below 9 years use both verbal cues and lateralized cues to orient their attention in an emotional dichotic listening task

Julien Donnot[ab], Marion Phelip[b], Colin Blättler[ab] & Jacques Vauclair[b]

[a] Human Factor and Operation Environment Department, Research Center of the French Air Force, Salon Air, France

[b] Research Center of the Psychology of Cognition, Language and Emotion (Center PsyCLE), University of Provence, Aix en Provence Cedex 1, France

Published online: 20 Dec 2013.

Laterality, 2014
Vol. 19, No. 5, 533–548, http://dx.doi.org/10.1080/1357650X.2013.868470

Routledge
Taylor & Francis Group

Children below 9 years use both verbal cues and lateralized cues to orient their attention in an emotional dichotic listening task

Julien Donnot[1,2], Marion Phelip[2], Colin Blättler[1,2], and Jacques Vauclair[2]

[1]Human Factor and Operation Environment Department, Research Center of the French Air Force, Salon Air, France
[2]Research Center of the Psychology of Cognition, Language and Emotion (Center PsyCLE), University of Provence, Aix en Provence Cedex 1, France

The current study aimed to demonstrate that children below 9 years of age efficiently orient their auditory attention with both verbal cues and lateralized cues to identify emotional stimuli. The use of emotional stimuli is an optimal condition according to the assumption that a multi-component task calling on different resources from the two cerebral hemispheres is easier than a multi-component task requiring resources from the same hemisphere. A sample of 103 right-handed children from 7 to 12 years of age was required to identify emotional speech made up of pseudowords preceded by a binaural verbal cue or by a lateralized tone cue. As expected, we observed better performance for the skilled ear (i.e., the left ear for emotional processing) and an improving effect of verbal cues. According to our success criterion (mean correct report rates significantly different from chance), an efficient control of orienting attention was observed in all groups of children. This means that children from 7 to 8 years of age were able to efficiently orient their attention to identify emotional stimuli. Results are discussed in relation to the hemispheric lateralization of emotions.

Keywords: Attention; Dichotic listening task; Emotions; Hemispheric specialization.

The present study focuses on the ability in 7- to 12-year-old children to orient their attention and to identify emotional tones in a dichotic listening paradigm. Since the studies in the visual field (Posner, 1980), it is accepted that attention can be oriented by two different ways: an exogenous way, elicited by a sudden

Address correspondence to: Julien Donnot, Human Factor and Operation Environment Department, Research Center of the French Air Force, BA 701, 13661 Salon Air, France. E-mail: Julien.donnot@univ-amu.fr

change in the environment and soliciting an automatic attention, and an endogenous way, elicited by the projects of the individual itself and soliciting a voluntary attention. According to Posner's conclusions, Camus (1996) explained the orientation of the auditory attention by integrating a lateralized tone cue, presented monaurally to one ear, as a sudden external event that attracts attention exogenously and then activate bottom-up processes. Conversely, this author considered a verbal cue, presented binaurally, as a symbol requiring an interpretation which attracts attention endogenously and then activates top-down processes (e.g., Posner & Petersen, 1990).

The dichotic listening task to study orientation of auditory attention

Auditory perception is usually investigated via dichotic listening tests (DLTs) (e.g., Hugdahl & Andersson, 1986; Mondor & Bryden, 1991, 1992; Obrzut, Horgesheimer, & Boliek, 1999 and see Hugdahl, 2011 for a presentation of 50 years of dichotic listening research), even though this technique presents several shortcomings (i.e., the attentional bias: see Hiscock & Kinsbourne, 2011; Mondor & Bryden, 1991, 1992). This empirical technique, which originally served to assess auditory laterality (e.g., Bryden, 1988; Kimura, 1964, 1967; Obrzut, 1988), involves the presentation at the same time of stimuli to both the left and right ears to measure lateralized differences in performance. The stimulus presented to the left ear differs from the stimulus presented to the right ear. According to the two main models of dichotic listening proposed by Kimura (1967), the efficiency of stimulus processing may vary with respect to the specialization of the solicited hemisphere. During a dichotic listening presentation, the ipsilateral auditory pathways are inhibited and information is only transferred via the contralateral pathways. Thus, two models, the *direct access model* and the *callosal relay model*, have been proposed to explain the nature of the stimulus processing. According to the *direct access model*, the stimulus presented to one ear is directly processed by the contralateral hemisphere. According to the *callosal relay model* the stimulus is transferred via the *corpus callosum* to the specialized hemisphere depending on the nature of the stimuli. A verbal stimulus presented to the left ear is transmitted directly to the right hemisphere but is then transferred to the left hemisphere because of the left hemisphere's specialization for language processing. Thus, differences in performance are mainly attributed to cerebral specialization. Several studies have shown that adults and children report verbal stimuli presented to the right ear faster and more accurately. This right-ear advantage (REA) may result from a left-hemisphere specialization for verbal information processing (Asbjørnsen & Hugdahl, 1995; Mondor & Bryden, 1991; Obrzut et al., 1999). Conversely, auditory emotional stimuli are preferentially recognized via the left ear (left-ear advantage; LEA), presumably reflecting a right-hemisphere specialization for emotional auditory information processing (Erhan, Borod, Tenke, & Bruder, 1998; Ley & Bryden, 1982; Mahoney & Sainsbury, 1987). However, an LEA does not only signal emotional processing in the right hemisphere, as it is also observed in the identification of other nonverbal stimuli, such as melodies (Kimura, 1964; Obrzut, Boliek, & Obrzut, 1986). An alternative model proposed by Kinsbourne (1970, 1973, 1975, 1980) suggests that attention is oriented to the right perceptual field consecutively to the greater activation of the left hemisphere by verbal stimuli compared to the right hemisphere. Thus, an orienting attention task may be biased because of the imbalance in hemispheric activation. This model is supported by studies showing an LEA in the identification of emotional stimuli (e.g., Bryden & MacRae, 1988; Donnot & Vauclair, 2007) but it could be interesting to put this model to test with a task requiring the focus on one ear with a verbal cue (greater activation of the left hemisphere) to identify an emotion (greater activation of the right hemisphere).

Cueing in the dichotic listening task

Before stimulus presentation, one ear needs to be cued in the forced ear paradigm. Camus (1996) discussed the effects of different stimulus onset asynchrony (SOA) found when attention is oriented by a lateralized tone cue. In effect, several authors (Gadea & Espert, 2009; Mondor & Bryden, 1991; Obrzut, Boliek, & Asbjornsen, 2006) showed that the time interval between the beginning of the tone cue and the beginning of the presentation of dichotic stimuli had an effect on performance of children and adults. These latter authors found that from 150 ms SOA to 450 ms SOA, participants efficiently allocated their attention on the right and left ears but children showed difficulties to orient their attention to the left ear even with longer SOA (Obrzut et al., 1999). We assume that automatic attention solicited by the tone cue is not efficient enough above 450 ms SOA. Concerning verbal cues, Camus (1996) demonstrated that even with 1000 ms SOA, adults showed very high performance on the right and left ears, when having to detect consonant–vowel syllables. Thus, to control for a potential effect of SOA, we will use cross conditions with both types of cues. Because we will use two types of cues which have different durations in the current study, it seems appropriate to control for an interstimulus interval (ISI) effect that is the time interval between the end of the cue and the beginning of the stimulus.

Orienting auditory attention in children

Several studies were devoted to children performance for orienting auditory attention (Andersson & Hugdahl, 1987; Andersson, Llera, Rimol, & Hugdahl, 2008; Hugdahl, Carlsson, & Eichele, 2001; Obrzut et al., 1999). Nevertheless, these authors investigated separately orientation with a verbal cue (Andersson & Hugdahl, 1987; Andersson et al., 2008; Hugdahl et al., 2001) and orientation with a lateralized tone cue (Mondor & Bryden, 1992; Obrzut et al., 1999). Only Obrzut et al. (2006) observed performance in 9- to 13-year-old children with both tone and verbal cues and showed an increased accuracy with verbal cues. When requested via a verbal cue to detect verbal stimuli, only 9-year-old children or above can correctly detect stimuli both in the right and left ears (Andersson & Hugdahl, 1987; Andersson et al., 2008; Hugdahl et al., 2001). Consequently, only children above 9 years of age are able to orient efficiently their attention endogenously and control it as adults do. Below this age, they have more accurate detection rates in conditions of exogenous orientation of attention. In fact, when oriented by a lateralized tone cue, children below 9 years of age enhanced their performance (Obrzut et al., 1999), contrarily to a non-forced orientation condition. Hiscock and Beckie (1993) showed that 7-year-olds efficiently oriented their attention when they were alerted by a lateralized tone cue. A reason why children below the age of 9 are unable to use efficiently verbal cues may be a deficiency in cognitive flexibility and inhibition processing due to an immature frontal cortex (Kanemura, Aihara, Aoki, Araki, & Nakazawa, 2003; Li, Gratton, Fabiani, & Knight, 2013).

According to Falkenberg, Specht, and Westerhausen (2011), the activation of top-down processes, which plays a major role in cognitive flexibility, seems to be more dependent upon the frontal cortex than the activation of bottom-up processes. The recruitment of top-down processes, activated by the frontal cortex, appears to constitute a major difficulty for children under the age of 9 (Hwang, Velanova, & Luna, 2010; Li et al., 2013). Thus, children below the age of 9 might be unable to use verbal cues because they have difficulties to solicit top-down processes.

Another explanation could be that children below 9 years of age have a left hemisphere overload induced by the verbal cue processing combined to the verbal stimuli processing. Kinsbourne and Hicks (1978) proposed that a multi-component task (i.e., verbal cue and emotional stimuli in the current study) calling on different resources from different hemispheres is easier than a multi-component task requiring resources from the same hemisphere. In the current study we plan to test children in specific conditions in order to allow for an optimal distribution of mental workload. The combination of verbal cues, soliciting the left hemisphere, with the presentation of emotional stimuli, soliciting the right hemisphere, should improve the children's performance below the age of 9 years.

It has been showed in previous studies (Donnot, 2007; Donnot & Vauclair, 2007) that the emotional stimuli we will use in the current emotional dichotic listening task are better perceived in the left ear, that means are better processed by the right hemisphere. These results are congruent with those of Bryden and MacRae (1988) in adults and those of Saxby and Bryden (1984) in children. We do not support the assumption of an exclusive right hemisphere processing for emotional stimuli, but we consider that the right hemisphere is more heavily involved than the left in the perception of emotional tones, whatever their valence. Moreover, we agree with the idea that emotional stimuli require the activation of top-down processes in order to be identified (Pessoa, Kastner, & Ungerleider, 2002; Sauter & Eimer, 2010; Schirmer & Kotz, 2003; see Watling, Workman, & Bourne, 2012 for a review on emotion lateralization).

Goal of the current study

The current study aimed to demonstrate that children below 9 years of age can efficiently orient their auditory attention with verbal cues to identify emotional stimuli. First, for Kinsbourne and Hicks (1978), a multi-component task (i.e., verbal cue and emotional stimuli in the current study) calling on different resources from different hemispheres is easier than a multi-component task requiring resources from the same hemisphere. Consequently, we can expect significantly better performance than chance in children below 9 years of age with both verbal cues and lateralized tone cues. Second, we can expect an improving effect of the verbal cues as the pre-activation of top-down processes by the verbal cues may facilitate the identification of emotional stimuli. Nonetheless, it is difficult to state if our emotional stimuli are easier to detect than verbal stimuli. The emotional stimuli we used are 2 s long and we chose to present three well-marked tones, namely an angry, happy and neutral tone.

Concerning the use of short and long ISI, we expected an interaction between ISI and the Cue Type on the children's performance. Higher correct responses rate should be observed for the combination of short ISI with lateralized tone cues and the combination of long ISI with verbal stimuli.

METHOD

Participants

The participants were 103 healthy children from an elementary school and a middle school. We checked that none of the participants had auditory problems or attention deficit disorders. Teachers, aware of the content of the Child Health Record can exclude children from the selection. One child was excluded before experimentation for auditory problems. This experiment received the written consent of the parents, teachers and school directors. Children were divided into three age groups. The 7–8 years group (n = 34; M = 7.73; SD = .46) was composed of 19 girls (M = 7.70; SD = .52) and 15 boys (M = 7.77; SD = .39); the 9–10 years group (n = 40; M = 10.14; SD = .56) was composed of 22 girls (M = 10.16; SD = .59) and 18 boys (M = 10.11; SD = .52) and the 11–12 years group (n = 29; M = 11.77; SD = .57) was composed of 12 girls (M = 11.90; SD = .54) and 17 boys (M = 11.68; SD = .59). All the children were right-handed. Handedness was assessed with the Edinburgh Handedness Inventory (Oldfield, 1971).

Stimuli

We used the stimuli designed by Donnot and Vauclair (2007), for which the capability to solicit a right hemisphere processing has been demonstrated in several studies (Donnot, 2007; Donnot & Vauclair, 2007, 2011; Donnot, Vauclair, & Bréjard, 2008). These emotional stimuli comprised five sentences (duration between 1.55 and 1.95 s) made up of several pseudowords and read aloud by a male speaker in three emotional tones (angry, neutral and happy). We decided to use pseudowords instead of sounds to facilitate the application of emotional intonation and to limit the left hemisphere involvement in semantic processing. Thus, a left hemisphere overload should be avoided. For each sentence, we formed emotional pairs using all possible combinations, including reverse pairs. Six different combinations (angry/neutral, angry/happy, neutral/happy and reversed pairs neutral/angry, happy/angry and happy/neutral) were created in this way for each sentence, making a total of 30 dichotic pairs.

The lateralized tone cue was a *beep* (duration 100 ms) played either to the left ear or to the right ear, whereas the verbal cue was the word "left" (duration 550 ms) or "right" (duration 550 ms) presented binaurally. The interval between the end of the presentation of the cue and the dichotic pair presentation was either 100 ms, to favour the effect of the lateralized cue, or 650 ms, to favour the effect of the verbal cue (Obrzut et al., 1999).

Emotional dichotic listening tasks

Combinations of cues (verbal cues vs. lateralized tones), forced ear (left vs. right), interval (100 ms vs. 650 ms) and the three emotional tones (happy, neutral and angry) generated 48 trials for each sentence, that is, a total of 240 different pairs. We created five blocks which differed from each other only in the sentences associated with each dichotic pair. In short, each block included all the sentences but not for the same pairs. For example, the *happy/neutral with left ear forced, verbal cue and a 650-ms interval* trial was associated with Sentence 1 in Block 1, but with Sentence 4 in Block 2. Each block was divided in two sub-blocks, the binaural verbal cue block and the lateralized tone cue block. Thus, participants responded either to the 24 trials of the verbal cue sub-block first, then the 24 trials of the lateralized tone sub-block, or vice versa. We controlled for potential effects of the block and the order of sub-block presentation.

Trials were presented on a portable computer running DMDX open-source software with Sennheiser HD 415 headphones. Participants had 4 s to give their response by pressing one of three marked keys on the keyboard (happy, neutral and angry). No response was recorded after 4 s had elapsed. Children were tested individually in the classroom attended by the experimenter and a teaching assistant. Selected keystrokes and response times were recorded. We calculated the mean correct report rates for each participant in each condition according to the following ratio: *number of correct reports/number of reports*. Errors included responses to the non-forced ear and incorrect identification of the emotional tone. Omissions could not be systematically counted as errors and have thus been excluded from the analyses.

Criterion for success

We decided to define a success criterion according to the number of potential responses that is 33% (i.e., a mean correct report rate significantly higher than .33). In fact, the participant was proposed a three-choice response: anger, happiness or neutral tone. As the experimental set-up did not allow us to state if children failed to identify emotional stimuli or to efficiently orient their attention, we kept a statistical benchmark.

RESULTS

Methodological controls

We began by controlling for potential effects of the block factor, the order factor and the gender. An analysis of variance (ANOVA) with correct report rate as the dependent variable showed neither effect of order, $F(1, 83) = 1.31$, $p = .26$, nor block, $F(4, 83) = .29$, $p = .89$, nor gender, $F(1, 83) = 2.58$, $p = .11$, on the children's performance.

Omissions

The percentage of omissions was similar in 7- to 8- and 9- to 10-year-olds and equal to 16%. In 11- to 12-year-olds, omissions represent 6% of the trials.

DLT performance compared to the success criterion

Then, we compared mean scores of each age group to the success criterion (i.e., .33) and observed that all the groups of children reached success: 7–8 years group: $M = .59$, $SD = .18$; $t(33) = 8.61$, $p < .001$, Cohen's $d = 2.04$; 9–10 years group: $M = .70$, $SD = .19$; $t(39) = 12.59$, $p < .001$, Cohen's $d = 2.75$: 11–12 years group: $M = .74$, $SD = .17$; $t(28) = 13.04$, $p < .001$, Cohen's $d = 3.41$ (see Figure 1).

Further analyses focused on the effects of age groups, forced ear, nature of cues and ISI. An ANOVA was conducted on correct report rates, with the forced ear (left vs. right), the nature of the cue (binaural verbal vs. lateralized tone) and the ISI (100 vs. 650 ms) as the within-groups factors and age (7–8, 9–10 and 11–12 years) as the between-groups factor (see Table 1).

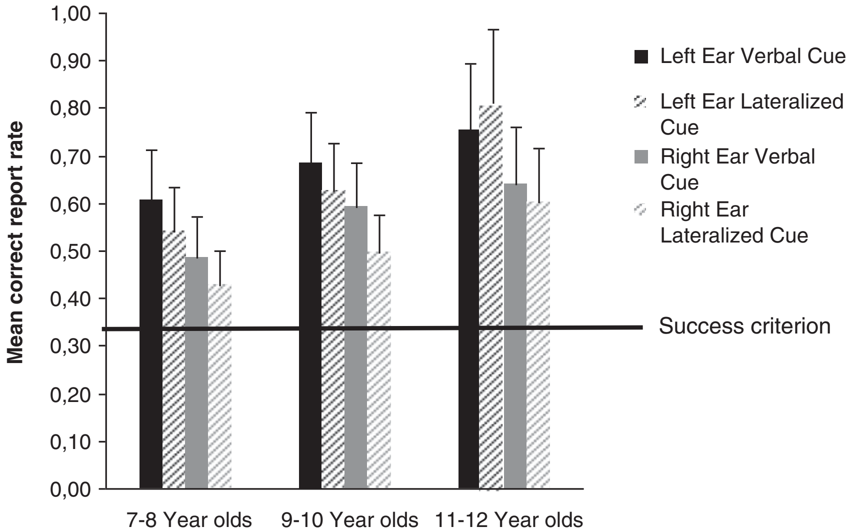

Figure 1. Mean correct report rates for each age group according to the nature of cues and to the focused ear. The bold line represents the success criterion (.33). Errors bars are SEM (standard error of the mean).

TABLE 1
Effects and interaction effects resulting from the ANOVA conducted on correct report rates, with the forced ear (left vs. right), the nature of the cue (binaural verbal vs. lateralized tone) and the ISI (100 vs. 650 ms) as the within-groups factors and age (7–8, 9–10 and 11–12 years) as the between-groups factor

	Sum of squares	*Degrees of freedom*	*Mean of squares*	F	p	*Full* η^2	*Power analysis*
Age	2.97	2	1.48	5.61	.00	8.00E−03	0.85
Ear	3.09	1	3.09	28.80	.00	8.00E−03	1
Ear × age	0.10	2	0.05	0.46	.63	3.00E−04	0.12
Cue	0.30	1	0.30	4.86	.03	8.06E−04	0.59
Cue × age	0.16	2	0.08	1.32	.27	4.37E−04	0.28
ISI	0.05	1	0.05	1.34	.25	1.32E−04	0.21
ISI × age	0.04	2	0.02	0.55	.58	1.09E−04	0.14
Ear × cue	0.16	1	0.16	4.27	.04	4.15E−04	0.53
Ear × cue × age	0.08	2	0.04	1.04	.36	2.02E−04	0.23
Ear × ISI	0.01	1	0.01	0.22	.64	1.94E−05	0.07
Ear × ISI × age	0.10	2	0.05	1.54	.22	2.76E−04	0.32
Cue × ISI	0.01	1	0.01	0.31	.58	2.39E−05	0.09
Cue × ISI × age	0.14	2	0.07	2.31	.11	3.59E−04	0.46
Ear × cue × ISI	0.00	1	0.00	0.08	.78	5.84E−06	0.06
Ear × cue × ISI × age	0.07	2	0.03	1.21	.30	1.79E−04	0.26

Age effect

We observed an effect of the age groups (see Table 1). The older the children were the higher the performance was. Planned comparison analyses showed a significant difference between mean scores of 7–8 years group and 9–10 years group [$F(1, 100) = 6.52$, $p = .001$, Cohen's $d = -.59$], whereas no significant difference was found between the 9–10 years and 11–12 years groups [$F(1, 100) = .68$, $p = .41$, Cohen's $d = -.22$].

Focused ear effect

We observed an effect of the forced ear (see Table 1) with a significant higher mean score for the left ear ($M = .75$, $SD = .32$) than for the right ear ($M = .62$, $SD = .35$).

Nature of cue effect

We observed an effect of the cues (see Table 1) with a significant higher mean score for the verbal cues' condition ($M = .70$, $SD = .33$) than for the lateralized tone cues' condition ($M = .66$, $SD = .35$). Results are illustrated in Figure 1.

ISI effect

We observed neither significant effect of ISI nor interaction with the nature of the cue (see Table 1).

Interaction

We observed an interaction between the forced ear and the nature of cues (see Table 1). Planned comparisons showed no significant difference between the verbal condition ($M = .75$, $SD = .24$) and the lateralized cue condition ($M = .73$, $SD = .24$) when the left ear was forced [$F(1, 100) = .29$, $p = .59$, Cohen's $d = .08$]. By contrast, mean scores in the verbal cue condition were significantly higher ($M = .65$, $SD = .27$) than mean scores in the lateralized cue condition ($M = .59$, $SD = .25$) when the right ear was forced [$F(1, 100) = 7.78$, $p = .006$, Cohen's $d = .23$].

DISCUSSION

Absence of ISI effects

We failed to observe an effect of the ISI factor and an interaction between the ISI factor and the nature of cues on mean correct report rates. Although we collected data on mean response times, they were not included in our analyses. The reason for not using them is that the children tended to wait for the end of the stimuli presentation to respond and this strategy led to a ceiling effect of mean response times.

Children younger than 9 years of age efficiently orient their attention to identify auditory emotional stimuli.

Our results showed that performance of all the age groups are significantly higher than the chance probability (33%). Then, the current study demonstrated that from 7 to 8 years of age children are able to efficiently orient their attention to identify auditory emotional stimuli according to specific conditions. These conditions are now discussed in order to better understand orienting attention in children. Compared to several studies using verbal stimuli (e.g., Andersson & Hugdahl, 1987; Andersson et al., 2008; Hugdahl et al., 2001), we observed a younger age of success for an emotional dichotic listening task possibly due to the use of emotional stimuli.

Effect of the focused ear

The LEA we observed is also widely reported in the literature for adult participants, despite some inconsistencies across studies (for reviews, see Demaree, Everhart, Youngstrom, & Harrison, 2005; Gainotti, 1984). Moreover, this LEA is frequently found in studies using a DLT (e.g., Bryden & MacRae, 1988; Donnot, 2007). Our results showed an overall improvement in children's performance of the identification of an emotional tone when the left ear was cued, rather than the right ear, in accordance with the studies using emotional auditory stimuli.

Developmental considerations: Gradual control of attention

The effect of age we found indicates that correct report rates increased whichever ear was focused and whichever cue was used as no significant interaction effect of age group and the named factors was found. Moreover, there was enough statistical power to detect the effect if there had been one. We can, therefore, conclude that the mechanisms subtending the control of orienting attention in children are not *all or nothing* mechanisms but we observed a sudden break between the youngest age group and the two older ones. Nonetheless, the fact that successful emotion identification was better for the left ear than for the right ear, combined with the available literature, suggests that children's efficiency in orienting their attention is contingent upon the nature of the information being processed. This leads us to conclude that task difficulty in the DLT is an obstacle to success rather than a means of focusing on the ability to orient attention. A difficult task should be a task that implies an overload of the left hemisphere.

Effect of verbal cues

By using emotional stimuli, our results confirmed that children below 9 years of age efficiently use lateralized tone cues as already shown by Obrzut et al. (1999) and Hiscock and Beckie (1993) but there is a difference in favour of verbal cues performance in the youngest age group like in all other groups. Thus, children below 9 years of age orient their attention with verbal cues for identifying emotional stimuli, whereas they are unable to identify verbal stimuli before the age of 9 (Andersson & Hugdahl, 1987; Andersson et al., 2008; Hugdahl et al., 2001).

Our results confirmed the assumption made by Kinsbourne and Hicks (1978) that a multi-component task (i.e., verbal cues and emotional stimuli in the current study) calling on different resources from different hemispheres is easier than a multi-component task requiring resources from the same hemisphere. Indeed, while the left ear is forced, emotional stimuli imply a reduction of cognitive resources required by the left hemisphere, given that the right hemisphere is engaged in the emotional stimuli processing. The processing of verbal cues by the left hemisphere is facilitated as well as the identification of the emotional stimuli by the right hemisphere and this explains the better performance for the left ear than for the right ear. While the right ear is forced, two explanations may be suggested: the left hemisphere is in charge of verbal cues and then emotional stimuli processing (referring to the *direct access model*). Thus, we should not have observed success in our results for children under 9 years of age in conformity with the literature, except if we consider that emotional processing uses fewer cognitive resources than language, which has been demonstrated by Obrzut et al. (1986); otherwise, according to the *callosal relay model*, the left hemisphere transfers the emotional stimulus to the right hemisphere instead of processing it itself (Banich, 1997). This possibility may explain why children below 9 years of age succeeded in the emotional dichotic listening task but showed lower results in the right ear than in the left ear. These results are congruent with reports of enhanced verbal identification performance in children with learning disabilities due to the use of lateralized tone cues (Obrzut et al., 2006). Our results also confirm the left-hemisphere specificity for processing verbal cues and these latter authors suggested that the children in their sample might have compensated for their weak left-hemisphere abilities by engaging the right spatial hemisphere more strongly.

Top-down processes responsible for the efficient use of verbal cues

Beyond the fact that children below 9 years of age efficiently used verbal cues to identify emotional stimuli, we observed that children better performed with verbal cues than with lateralized tone cues whatever their age, as no interaction effect of age group and nature of cues was found. An explanation in terms of cognitive control can be suggested. In fact, verbal cues by contrast to lateralized tone cues require top-down processes (Posner & Petersen, 1990) and they may also be involved in emotional stimuli identification (Pessoa et al., 2002; Sauter & Eimer, 2010; Schirmer & Kotz, 2003). Thus, verbal cues may pre-activate top-down processes, which probably facilitated the correct identification of emotional stimuli. The significant interaction between the nature of cues and the forced ear may be interpreted as well. Identification of emotional stimuli is easier in the left ear than in the right ear because of the specialization of the right hemisphere to process emotions. But, when the right ear is forced, verbal cues could facilitate the correct identification of emotional stimuli compared to the lateralized cues' condition. Thus, the attentional model of Kinsbourne (e.g., 1970) is strongly supported in the way that verbal cues pre-activate the left hemisphere and orient attention to the contralateral perceptual field, namely the right ear. By contrast, our results did not support the hypothesis that children below the age of 9 are unable to use verbal cues due to an immature frontal cortex which is responsible for the activation of top-down processes. If we agree with the fact that the frontal cortex is not fully developed at this age, we consider that youngest children are restricted in their capacity to activate top-down processes and that the optimal configuration proposed by our experimental set-up gave them the opportunity to efficiently solicit top-down processes via the use of verbal cues.

Comparisons with adults' data

Our research group collected data in adults but the results are not yet published. However, adults showed the same ear effect than children, that is a better performance for the left ear (i.e., mean correct response rate = .93) than for the right ear (M = .85). Adults also showed a higher global performance than the older children group in the current study (M = .74) according to the gradual control of attention mentioned at the beginning of the discussion.

Limitations of the study

The emotional stimuli we used, namely sentences made by pseudowords pronounced with emotional tones, led us to observe a better performance for the left than for the right ear, which confirmed the emotional component of our stimuli. Nevertheless, we cannot neglect the verbal component of our stimuli as they were represented by nonsense words, and, consequently, we cannot ignore that this verbal part may have an effect on the emotional dichotic listening task performance.

The power of the DLT to predict hemispheric lateralization has been questioned (e.g., Lee, Loring, Newell, & Meador, 1994; Teng, 1981), and

Mondor and Bryden (1991) have suggested that researchers should control for attentional processing when collecting data with a verbal DLT. It is thought that an attentional bias may be responsible for the increased REA observed with verbal stimuli, in that it may be easier to identify a stimulus presented to the right ear than one presented to the left because of a tendency to attend more to the right ear than to the left. However, given that the current study featured an experimental method that controlled for the effect of attentional bias, the enhanced performance of the left ear cannot be ascribed to it. Two explanations can be put forward. First, the attentional bias mentioned by Mondor and Bryden (1991) concerns the identification of verbal stimuli, which are supposed to be perceived better by the right ear. Second, we observed an LEA even though the orientation of attention had been forced equally to the left and right ears. Consequently, this LEA was probably due to a right-hemisphere advantage for emotional processing. This advantage was observed despite the beneficial effect of the right-ear attentional bias.

Another limitation of the current study is that our experimental methodology was not designed to make an accurate distinction between exogenous and endogenous attention effects. Indeed, we deliberately chose relatively lengthy stimuli (≈2 s) specifically to stimulate endogenous attention. They also needed to be long to suit the constraints of a children's population. The two conditions (i.e., binaural verbal cues vs. lateralized tone cues) can be assumed to have stimulated endogenous attention in two different manners: the verbal cues' condition represented a direct stimulation of voluntary attention in that it resulted in the allocation of substantial attentional resources to the cued ear. In the lateralized tone cues' condition, reflex attention was initially oriented to the cued ear, but then required sustained attention. It is legitimate to wonder whether the difficulty of our task when the right ear was forced resulted from an inability to inhibit information processing by the skilled hemisphere (i.e., the right hemisphere), as suggested by some authors (e.g., Hugdahl et al., 2009) or from the difficulty of highlighting information processing by the nonskilled hemisphere (i.e., the left hemisphere). The verbal cues' condition, characterized by direct stimulation of endogenous attention, may facilitate the inhibition of irrelevant stimuli presented to the noncued ear. Soveri, Laine, Hämäläinen, and Hugdahl (2011) found that bilingual participants performed better than monolingual participants on a syllabic forced-attention dichotic listening task, the former being known to be more skilled than the latter in inhibiting task-irrelevant information (Bialystok, 2001). Our results do not allow us to answer this question, but we intend to investigate it in future studies.

Manuscript received 30 July 2013
Revised manuscript received 13 November 2013
Revised manuscript accepted 18 November 2013
First published online 19 December 2013

REFERENCES

Andersson, B., & Hugdahl, K. (1987). Effects of sex, age, and forced attention on dichotic listening in children: A longitudinal study. *Developmental Neuropsychology*, *3*, 191–206. doi:10.1080/87565648709540376

Andersson, M., Llera, J. E., Rimol, L. M., & Hugdahl, K. (2008). Using dichotic listening to study bottom-up and top-down processing in children and adults. *Child Neuropsychology*, *14*, 470–479. doi:10.1080/09297040701756925

Asbjørnsen, A. E., & Hugdahl, K. (1995). Attentional effects in dichotic listening. *Brain and Language*, *49*, 189–201. doi:10.1006/brln.1995.1029

Banich, M. T. (1997). *Neuropsychology – the neural bases of mental function*. Boston, MA: Houghton-Mifflin.

Bialystok, T. (2001). *Bilingualism in development: Language, literacy and cognition*. New York, NY: Cambridge University Press.

Bryden, M. (1988). An overview of the dichotic listening procedure and its relation to cerebral organization. In K. Hugdahl (Ed.), *Handbook of dichotic listening: Theory, methods and research* (pp. 1–43). New York, NY: John Wiley & Sons.

Bryden, M. P., & MacRae, L. (1988). Dichotic laterality effects obtained with emotional words. *Neuropsychiatry, Neuropsychology, and Behavioral Neurology*, *1*, 171–176.

Camus, J.-F. (1996). Maintien durable de l'orientation de l'attention en écoute dichotique: Comparaison entre un avertisseur verbal et un avertisseur sonore latéralisé [Auditory orienting of attention in dichotic listening]. *L'Année Psychologique*, *96*(1), 31–52. doi:10.3406/psy.1996.28876

Demaree, H. A., Everhart, D. E., Youngstrom, E. A., & Harrison, D. W. (2005). Brain lateralization of emotional processing: Historical roots and a future incorporating "dominance". *Behavioral and Cognitive Neuroscience Reviews*, *4*(1), 3–20. doi:10.1177/1534582305276837

Donnot, J. (2007). Lateralization of emotion predicts infant holding bias in left-handed students, but not in left-handed mothers. *Laterality*, *12*, 216–226.

Donnot, J., & Vauclair, J. (2007). Infant holding preferences in maternity hospitals: Testing the hypothesis of the lateralized perception of emotions. *Developmental Neuropsychology*, *32*, 881–890. doi:10.1080/87565640701539774

Donnot, J., & Vauclair, J. (2011). Infant holding side biases: Comparisons of laterality patterns in childcare professionals and mothers or students. *Laterality*, *16*, 280–291.

Donnot, J., Vauclair, J., & Bréjard, V. (2008). Newborn right-holding is related to depressive symptoms in bottle-feeding mothers but not in breastfeeding mothers. *Infant Behavior & Development*, *31*, 352–360. doi:10.1016/j.infbeh.2007.12.013

Erhan, H., Borod, J. C., Tenke, C. E., & Bruder, G. E. (1998). Identification of emotion in a dichotic listening task: Event-related brain potential and behavioral findings. *Brain and Cognition*, *37*, 286–307. doi:10.1006/brcg.1998.0984

Falkenberg, L. E., Specht, K., & Westerhausen, R. (2011). Attention and cognitive control networks assessed in a dichotic listening fMRI study. *Brain and Cognition*, *76*, 276–285. doi:10.1016/j.bandc.2011.02.006

Gadea, M., & Espert, R. (2009). A comparison of the effects for sustained versus shifted attention on dichotic listening performance. *Laterality*, *14*, 315–328.

Gainotti, G. (1984). Some methodological problems in the study of the relationships between emotions and cerebral dominance. *Journal of Clinical Neuropsychology*, *6*(1), 111–121. doi:10.1080/01688638408401201

Hiscock, M., & Beckie, J. L. (1993). Overcoming the right-ear advantage: A study of focused attention in children. *Journal of Clinical and Experimental Neuropsychology*, *15*, 754–772. doi:10.1080/01688639308402594

Hiscock, M., & Kinsbourne, M. (2011). Attention and the right-ear advantage: What is the connection? *Brain and Cognition*, *76*, 263–275. doi:10.1016/j.bandc.2011.03.016

Hugdahl, K. (2011). Fifty years of dichotic listening research – Still going and going and… *Brain and Cognition*, *76*, 211–213. doi:10.1016/j.bandc.2011.03.006

Hugdahl, K., & Andersson, L. (1986). The "forced-attention paradigm" in dichotic listening to CV-syllables: A comparison between adults and children. *Cortex*, *22*, 417–432. doi:10.1016/S0010-9452(86)80005-3

Hugdahl, K., Carlsson, G., & Eichele, T. (2001). Age effects in dichotic listening to consonant–vowel syllables: Interactions with attention. *Developmental Neuropsychology*, *20*, 445–457. doi:10.1207/S15326942DN2001_8

Hugdahl, K., Westerhausen, R., Alho, K., Medvedev, S., Laine, M., & Hämäläinen, H. (2009). Attention and cognitive control: Unfolding the dichotic listening story. *Scandinavian Journal of Psychology*, *50*(1), 11–22. doi:10.1111/j.1467-9450.2008.00676.x

Hwang, K., Velanova, K., & Luna, B. (2010). Strengthening of top-down frontal cognitive control networks underlying the development of inhibitory control: A functional magnetic resonance imaging effective connectivity study. *The Journal of Neuroscience*, *30*, 15535–15545. doi:10.1523/JNEUROSCI.2825-10.2010

Kanemura, H., Aihara, M., Aoki, S., Araki, T., & Nakazawa, S. (2003). Development of the prefrontal lobe in infants and children: A three-dimensional magnetic resonance volumetric study. *Brain and Development*, *25*, 195–199. doi:10.1016/S0387-7604(02)00214-0

Kimura, D. (1964). Left-right differences in the perception of melodies. *The Quarterly Journal of Experimental Psychology*, *16*, 355–358. doi:10.1080/17470216408416391

Kimura, D. (1967). Functional asymmetry of the brain in dichotic listening. *Cortex*, *3*, 163–178. doi:10.1016/S0010-9452(67)80010-8

Kinsbourne, M. (1970). The cerebral basis of lateral asymmetries in attention. *Acta Psychologica*, *33*, 193–201. doi:10.1016/0001-6918(70)90132-0

Kinsbourne, M. (1973). The control of attention by interaction between the cerebral hemispheres. In S. Kornblum (Ed.), *Attention and performance IV* (pp. 239–255). New York, NY: Academic Press.

Kinsbourne, M. (1975). The mechanism of hemispheric control of the lateral gradient of attention. In P. M. A. Rabbitt & S. Dornic (Eds.), *Attention and performance V* (pp. 81–97). London: Academic Press.

Kinsbourne, M. (1980). Dichotic imbalance due to isolated hemisphere occlusion or directional rivalry? *Brain and Language*, *11*, 221–224. doi:10.1016/0093-934X(80)90123-6

Kinsbourne, M., & Hicks, R. E. (1978). Functional cerebral space: A model for overflow, transfer, and interference effects in human performance. A tutorial. In J. Requin (Ed.), *Attention and performance VII* (pp. 345–362). Hillsdale: Erlbaum.

Lee, G. P., Loring, D. W., Newell, J. R., & Meador, K. J. (1994). Is dichotic word listening a valid predictor of cerebral language dominance? *Clinical Neuropsychologist*, *8*, 429–438. doi:10.1080/13854049408402045

Ley, R. G., & Bryden, M. P. (1982). A dissociation of right and left hemispheric effects for recognizing emotional tone and verbal content. *Brain and Cognition*, *1*(1), 3–9. doi:10.1016/0278-2626(82)90002-1

Li, L., Gratton, C., Fabiani, M., & Knight, R. T. (2013). Age-related frontoparietal changes during the control of bottom-up and top-down attention: An ERP study. *Neurobiology of Aging*, *34*, 477–488. doi:10.1016/j.neurobiolaging.2012.02.025

Mahoney, A. M., & Sainsbury, R. S. (1987). Hemispheric asymmetry in the perception of emotional sounds. *Brain and Cognition*, *6*, 216–233. doi:10.1016/0278-2626(87)90122-9

Mondor, T. A., & Bryden, M. P. (1991). The influence of attention on the dichotic REA. *Neuropsychologia*, *29*, 1179–1190. doi:10.1016/0028-3932(91)90032-4

Mondor, T. A., & Bryden, M. P. (1992). Orienting of auditory spatial attention: Effects of a lateralized tone cue. *Neuropsychologia*, *30*, 743–752. doi:10.1016/0028-3932(92)90043-L

Obrzut, J. E. (1988). Deficient lateralization in learning-disabled children: Developmental lag or abnormal cerebral organization? In D. L. Molfese & S. J. Segalowitz (Eds.), *Brain lateralization in children: Developmental implications* (pp. 567–589). New York, NY: Guilford Press.

Obrzut, J. E., Boliek, C. A., & Asbjornsen, A. (2006). Does attentional cueing affect dichotic listening performance in children? *Developmental Neuropsychology*, *30*, 791–800. doi:10.1207/s15326942dn3003_2

Obrzut, J. E., Boliek, C. A., & Obrzut, A. (1986). The effect of stimulus type and directed attention on dichotic listening with children. *Journal of Experimental Child Psychology*, *41*, 198–209. doi:10.1016/0022-0965(86)90058-5

Obrzut, J. E., Horgesheimer, J., & Boliek, C. A. (1999). A "threshold effect" of selective attention on the dichotic REA with children. *Developmental Neuropsychology*, *16*(1), 127–137. doi:10.1207/S15326942DN160108

Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh inventory. *Neuropsychologia*, *9*(1), 97–113. doi:10.1016/0028-3932(71)90067-4

Pessoa, L., Kastner, S., & Ungerleider, L. G. (2002). Attentional control of the processing of neutral and emotional stimuli. *Cognitive Brain Research*, *15*(1), 31–45. doi:10.1016/S0926-6410(02)00214-8

Posner, M. I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology*, *32*(1), 3–25. doi:10.1080/00335558008248231

Posner, M. I., & Petersen, S. E. (1990). The attention system of the human brain. *Annual Review of Neuroscience*, *13*(1), 25–42. doi:10.1146/annurev.ne.13.030190.000325

Sauter, D. A., & Eimer, M. (2010). Rapid detection of emotion from human vocalizations. *Journal of Cognitive Neuroscience*, 22, 474–481. doi:10.1162/jocn.2009.21215

Saxby, L., & Bryden, M. P. (1984). Left-ear superiority in children for processing auditory emotional material. *Developmental Psychology*, *20*(1), 72–80. doi:10.1037/0012-1649.20.1.72

Schirmer, A., & Kotz, S. A. (2003). ERP evidence for a sex-specific stroop effect in emotional speech. *Journal of Cognitive Neuroscience*, *15*, 1135–1148. doi:10.1162/089892903322598102

Soveri, A., Laine, M., Hämäläinen, H., & Hugdahl, K. (2011). Bilingual advantage in attentional control: Evidence from the forced-attention dichotic listening paradigm. *Bilingualism: Language and Cognition*, *14*, 371–378. doi:10.1017/S1366728910000118

Teng, E. L. (1981). Dichotic ear difference is a poor index for functional asymmetry between the cerebral hemispheres. *Neuropsychologia*, *19*, 235–240. doi:10.1016/0028-3932(81)90107-X

Watling, D., Workman, L., & Bourne, V. J. (2012). Emotion lateralisation: Developments throughout the lifespan. *Laterality*, *17*, 389–411.