こだわり	興味の幅の狭さ、考え事への没頭、物事のやり方、融通の利かなさなどの行動パターン、又は固執するもの、逆にどうしてもだめなものの程度により評価（対象は何でも構わず、物、やり方、順番、感触、回転物を眺めるなどでもいい）	特になし	興味の偏り、マイペースさ、凝り性、収集癖などがあるが、日常生活や周囲との関係で困ることはない	こだわりのため、日常生活や周囲との関係でギクシャクするが、配慮や工夫で大きな支障はない	こだわりのため、周囲がかなり合わせないと、日常生活に大きな支障がある	こだわっている対象から離れるのは極端に困難であったり、こだわりの強さのために他者との生活が困難であったりする	
		1	2	3	4	5	
感覚	特殊な感覚について評定し、どの感覚でもよい（苦手な音、カメラのフラッシュがだめ、太陽の光が痛い、又は逆に、小さな音、わずかな臭いなどに人より早く気付くなど）。スクリーンセーバーに見入る場合、視覚的好みとしては本項で、こだわる程度についてはこだわりの項で評定	特になし	多少あるが、通常の生活環境において困らない	本人の工夫（耳栓、サングラス等）や多少の環境調整（座席の配慮等）により、集団生活に支障がない	刺激となる対象を除去しない限り耐え難いため、大幅な環境調整がないと一般環境への適応は困難である	感覚過敏のために、環境調整を試みても、外出や他人との交流自体が困難である	
		1	2	3	4	5	
反復行動	くるくるまわる、ぴょんぴょんはねる、手をくねくね、ひらひらなどの体を動かす行動が無意識的に繰り返される	気になる点はない	退屈な時に時々あるが、気になるものではない	割と目立つが、制止したほうがいい場面で抑えがきくなど、大きくは困らない	反復運動が原因で社会生活に支障があるが、周囲の理解により過ごしていける	反復運動が常時みられるために、日常生活自体にも支障がある	
		1	2	3	4	5	
粗大運動	歩き方が変わっている、こけやすい、球技（周囲との協調性はここでは評価しない）、縄跳び、鉄棒、ケンケン、スキップが苦手など体のバランスの悪さがある。訓練の結果は避け、ハイハイ、独歩の時期など、乳幼児期からの運動発達も念頭に多角的に評価する。身体疾患からくるものは除く。持久力、瞬発力とは異なる	気になる点はない	多少バランスが悪いが、困らない（バランスの悪い方から1/4程度に入る）	体全体の動きがぎこちなく、バランスも悪く、それが要求される場面（体育のマット運動の時間など）では目立ってしまい、苦痛である	明らかなぎこちなさがあり、日常生活上も目立ちやすく、また狭いところを通り抜けづらいなどの不都合がある	体のバランスの悪さのために、安全面も含め、日常生活自体にも支障がある	
		1	2	3	4	5	
微細協調運動	ひもくくり、裁縫、お箸、はさみ、小さいボタンなどの細かい協調運動が苦手である。利き手や他の疾患、習慣（お箸の習慣のない場所で育った等）からくるものを除く。ピアノ、ワープロのみ得意など、訓練による結果を除き、発達的観点も含めて多角的に評価	気になる点はない	苦手であるが、困らない	お箸を使ってこぼれが目立つなど、手先の不器用さにより困ることはあるが、大きな支障ではない	手先の不器用さのために、特別な個別対応が必要である（ボタンのない服、特別なお箸など）	手先の不器用さのために、介助が必要など、日常生活自体にも支障がある	
		1	2	3	4	5	

不注意	物事の忘れが目立つ（忘れ物、約束の時間、頼まれた用件など）、課題を未完成で中止することが目立つ、ケアレスミスが多い、気が散りやすいなど（認知症、知的障害、加齢変化、単純な無関心によるものを除く）。限局した興味への集中や、考え事への没頭のみが理由で聞いていない場合は、こだわりで評定。幼児期は、過度の注意転導性、特に集団での指示や注意の入りにくさ、などを参考に評価	気になる点はない	負荷が大きい（すべきことが重なる、口論の後など）と不注意が目立ち始める	負荷が少なくても不注意が目立つが、本人の工夫や多少の環境調整により日常生活が送れる	不注意のために社会生活に支障があり、本人の努力や多少の環境調整では克服できない	不注意のために、交通安全面や身支度面など日常生活自体にとても支障がある	
		1	2	3	4	5	
多動	じっとしておくべきであると了解でき、特に嫌でない場面で落ち着きがない（こだわり等による目的があって動く場合や、常同的な動き、多忙などからくるものではなく、じっとしていられないという基準）	気になる点はない	じっとしておく場面で、体動や私語がややみられるが、着席はしており、問題とはならない	じっとしておく場面で、離席を含む体動や私語が目立つが、集団の流れを大きくは崩さない	会話中や何かに集中している時でなければ、じっとしておく場面で出入りや離席がとても目立つ	常に動いている感じで、じっとしておく場面にいることはできない	
		1	2	3	4	5	
衝動性	思い立つと止められない行動。会話の割り込み、衝動買い、順番を守れない、待てない、先を見通さない、その場しのぎの行動が目立つ等（普段は衝動的でないが、たまっていたものが時として噴出する場合は、こだわり、日頃のコミュニケーション不足、社会性の弱さなど、その要因で評価する。こだわりがもとだが、容易にパニックとなるなど複合要因の場合は、それぞれについて評価。環境因子によるものは、本評価からは除外し備考とする）	気になる点はない	多少あるが、特に問題とはならない	問題となることはあるが、周囲の多少の配慮や本人の工夫等で集団生活を送れる	抑制がきかない衝動的な行動があり、相当な理解がないと共同生活は困難である	衝動性のために孤立してしまう	
		1	2	3	4		
睡眠リズム	時差、当直、試験勉強、遊び等の事情でリズムが崩れる、ストレス環境下での不眠、服薬による影響を除き、落ち着いた状況で評価	ほぼ安定した時間帯に睡眠がとれている	短時間もしくは長時間睡眠であったり、時間帯が不安定だったりするが、特に問題とはならない	寝付けない、必要睡眠時間が長すぎる等で、日中も頻繁に眠く、日中の活動時間に支障がある。仕事、学校、しないとならない用事がある時は起きるが、そうでないときは、かなり崩れるなど	リズムは常に崩れ、通常の社会生活は困難だが、マイペースな時間帯を許されれば、社会生活を送れる	リズムの崩れのため、マイペースが許されても社会生活を送ることができない	
		1	2	3	4	5	

学習	計算、読字、書字など特定の領域において、知的レベル、学習不足では説明できない学習の困難さがある（未就学児は判定困難なため、空欄も可。学習不足の場合、例えば小学校1年生など学習に取り組んでいた時期に遡って検討）。作文や発表はコミュニケーションの項で評価、創造性も本項に含めない	計算、読字、書字の能力は、いずれも発達年齢相応である	計算、読字、書字のうち、発達年齢に比して不得意なものがあるが、困難というほどではない	計算、読字、書字のうち、発達年齢に不相応に困難なものがある	計算、読字、書字のうち、発達年齢に比して明らかな困難さがあるが、全くできないわけではない	計算、読字、書字のうち、全くできないものがある	
		1	2	3	4	5	
言語発達	本項目は言語発達面での判定であり、コミュニケーションに使えているかは「コミュニケーション」の項目で判定。初語、2語文の時期は非常に参考になるが、申告に頼りきらず、全体的な言語発達で評価	言語発達が遅いとは感じず（初語が1歳すぎまで、2語文が1歳代に出ていた）、言葉に不自然はない	やや遅めであったが（初語が1歳後半、2語文が2歳代に出た）、その後言語自体は年齢相当に獲得できている	幼少期、言語発達が遅く（初語2歳以降、2語文3歳以降）、その後も言語表現が不自然	言語発達は大幅に遅れ（小学校入学まで単語レベルであったなど）、その後も明らかな言語表現の間違いが目立つ（持っている言語能力であり、表面上の単語返しは、コミュニケーションで評定）	有意味語の発語がない	
		1	2	3	4	5	

得意分野	最も得意な分野で判定（特定のキャラクターのみなど、かなり限局したものは除く）	卓越した得意な分野がある	得意分野があり、周囲から一目置かれるが、卓越しているわけではない（周囲の人が全く真似できないと感じる程度ではない）	得意分野はあるが、目立たない	どちらかといえば、得意かなと思う分野がある	得意と感じる分野はない	
		1	2	3	4	5	

5. 謝辞

本評価尺度開発に当たり、下記の多くの方々にご協力いただいたことを深謝いたします。

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Development of a multi-dimensional scale for PDD and ADHD. Research in Developmental Disabilities. 32: 995–1003.

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＊特性チャート＊

年　　月　　日

1	2	3	4	5
		理解・配慮・支援		
気になる点はない	多少気になる点はあるが、通常の生活環境において困らない	本人の工夫や、周囲の多少の配慮で集団生活に適応（上司、担任など責任ある立場の人が把握し配慮する程度）	大幅な個別の配慮で集団生活に適応（上司、担任等の支援のみでは困難）	集団の流れに入るより、個人がより快適な生活を送れるような支援が優先される

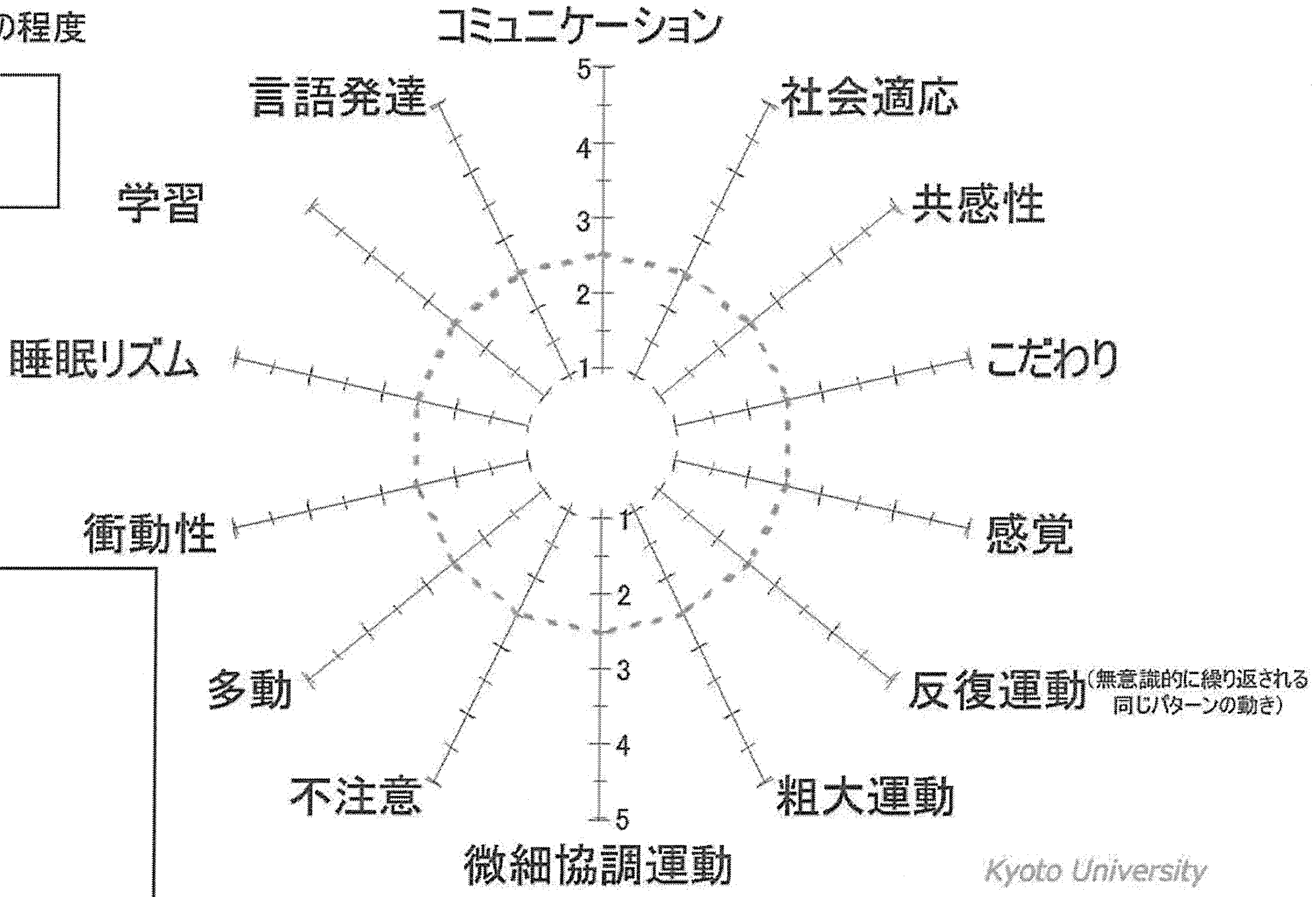
赤点線外がサポートの参考ラインです

得意分野、特技とその程度

DQ or IQ

全体；
動作性；
言語性；

その他の特記事項



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研究成果の刊行に関する一覧表

雑誌

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Funabiki Y, Kawagishi H, Uwatoko T, Yoshimura S, Murai T	Development of a multi-dimensional scale for PDD and ADHD	Research in Developmental Disabilities	32/3	995-1003	2011
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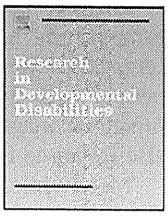

Cortical activation during attention to sound in autism spectrum disorders

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ABSTRACT

Individuals with autism spectrum disorders (ASDs) can demonstrate hypersensitivity to sounds as well as a lack of awareness of them. Several functional imaging studies have suggested an abnormal response in the auditory cortex of such subjects, but it is not known whether these subjects have dysfunction in the auditory cortex or are simply not listening. We measured changes in blood oxygenated hemoglobin (OxyHb) in the prefrontal and temporal cortices using near-infrared spectroscopy during various listening and ignoring tasks in 11 ASD and 12 control subjects. Here we show that the auditory cortex in ASD subjects responds to sounds fully during attention. OxyHb in the auditory cortex increased with intentional listening but not with ignoring of the same auditory stimulus in a similar fashion in both groups. Cortical responses differed not in the auditory but in the prefrontal region between the ASD and control groups. Thus, unawareness to sounds in ASD could be interpreted as due to inattention rather than dysfunction of the auditory cortex. Difficulties in attention control may account for the contrary behaviors of hypersensitivity and unawareness to sound in ASD.

1. Introduction

Autism spectrum disorder (ASD) is characterized by qualitative abnormalities of reciprocal social interaction, together with a restricted, stereotyped, repetitive repertoire of interests and activities. Infants with ASD may be first noticed to be unaware of being called, sometimes misunderstood as hearing disorders. In children with ASD, atypical auditory processing, such as auditory filtering difficulties or sensory under-responsiveness, is associated with academic underachievement (Ashburner, Ziviani, & Rodger, 2008). As they grow up, the unawareness decreases, but it usually persists more or less throughout life. On the other hand, autistic persons have been reported to show hypersensitivity to noise (Harrison & Hare, 2004; Leekam, Nieto, Libby, Wing, & Gould, 2007). Thus, behavioral response to sounds in ASD is inconsistent.

Several researchers have investigated this phenomenon. Behavioral and audiological studies have shown that behavioral responses to sounds are not associated with hypersensitivity of the auditory pathways but with difficulties in the higher cortical processing systems (Gomes, Rotta, Pedroso, Sleifer, & Danesi, 2004; Tharpe et al., 2006). Electrophysiological findings have indicated that sensory sound processing was intact but that involuntary orienting was affected (Ceponiene et al., 2003), and that the early left frontal component was abnormal, not the temporal component (Gomot, Giard, Adrien, Barthelemy, & Bruneau, 2002). Taken together, these findings suggest that the unawareness to sounds in ASD is not from dysfunction of the auditory pathway itself.

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Cortical response to sounds in the auditory area in autism has also been measured. Studies using positron emission tomography have shown cortical hypo-activation with passive listening to speech-like sounds in autism with mental retardation both in adults (Boddaert et al., 2003) and children (Boddaert et al., 2004). Gervais et al. (2004) reported that people with high-functioning autism (IQ: 81 ± 17.8) also had less activation in the superior temporal sulcus region with functional magnetic resonance imaging (fMRI) during passive listening to vocal sounds, and that recall of the presented voices was also impaired in subjects who had hypo-activation of that region.

Meanwhile, it has been established that attention modulates the activities of the auditory cortex (Grady et al., 1997; Jäncke, Mirzazade, & Shah, 1999; Petkov et al., 2004; Pugh et al., 1996; Rinne et al., 2007; Woods et al., 2009). When greater attention to sounds is demanded, there is more activation of the temporal lobe. Therefore, the findings of decreased response in the temporal lobe in autistic subjects may simply reflect decreased attention to sounds in autism, rather than impairment of auditory areas per se.

The purpose of this study was to clarify whether the hypo-activation in ASD was due to dysfunction of the auditory cortex or merely due to inattention to voices. Thus, we investigated whether the auditory cortex was activated while ASD participants listened to sounds intentionally. The use of the passive listening paradigm that was applied in the previous studies would not be sufficient to elucidate this issue. We recorded cortical response to sound during modulation of attention using near-infrared spectroscopy (NIRS) in ASD and controls.

2. Materials and methods

2.1. Participants

The characteristics of participants are shown in Table 1. Informed consent was obtained from all the participants. NIRS can measure real-time brain response without averaging repeated trials, which enables monitoring of brain activity during on-the-spot attention. To control the level of attention to sound stimuli, it was essential that the subjects were unimpaired in basic verbal ability. Thus, we selected participants without language delay or mental retardation but with distinct ASD symptoms, limiting the diagnoses of subjects to Asperger's disorder or pervasive developmental disorder (PDD) not otherwise specified by the definition of the Diagnostic and Statistical Manual of Mental Disorders – Fourth Edition – Text Revision (DSM-IV-TR) (American Psychiatric Association, 2000). Both of these belong to the category of ASD or PDD. Autistic disorder by definition was excluded because of the language delay.

2.2. Sound files preparation

Since previous researchers have reported poor responses to voices compared with non-verbal sounds in people with autism (Ceponiene et al., 2003; Gervais et al., 2004), we focused on the cortical response to voices, especially those of meaningful stories. We also prepared tone sounds just for comparison, but since tones and meaningful stories are very different, we inserted step-by-step transition stimuli: vowels (each tone sound was replaced with a vowel) and a meaningless syllable sequence (reverse syllable reading of the meaningful story). Sound files were set at 30 s. The first file was a succession of two kinds of pure tones. The duration of each tone was 100 ms and the file included 45 tones. Most sounds were 1-kHz (83%), with 2-kHz tones (17%) randomly presented to avoid boredom. The second file was a succession of two vowels "e" and "i" by a female voice. The presentation was the same as the first file; the sound "e" took the place of the 1-kHz tone. These files were made with MATLAB 6.0. The third file was a meaningless syllable sequence, made by reading syllables of the fourth files in reverse order. The fourth file was simple stories with 30 words read by a female voice.

2.3. Settings of NIRS

We set up 32 probes. Each probe was located at 3 cm intervals. Spatial resolution was 20–30 mm. For monitoring the activation of the prefrontal cortex, we used the channels located at 15 mm above Fp1 and Fp2 of the international 10–20 system for electrode placement. For the auditory cortex, we chose the central channel among the activated ones lower or posterior to F7 on the left side and F8 on the right side. We used the same channels through all the recordings in each participant. The recorded waves were stored on a computer with 130 ms intervals. Details on data acquisition are written in the paper by Matsuda and Hiraki (2006).

Table 1
Characteristics of participants. Age and IQs are shown in means ± standard variations. Group differences were analyzed using student *t*-tests.

	ASD	Control	*P*
Number	11	12	
Male:female	10:1	10:2	
Age	16.8 ± 6.1	14.2 ± 3.8	0.22
FIQ	110.1 ± 10.9	102.9 ± 13.6	0.18
VIQ	112.5 ± 12.5	101.5 ± 12.6	0.048
PIQ	105.3 ± 12.8	103.8 ± 15.0	0.797

2.4. Data recording

Participants sat in front of a display with a simple meaningless screensaver, and put on a helmet-like apparatus with a multiple-channel NIRS (up to 46 channels, OMM-3000; Shimadzu Co., Japan). Two speakers were placed on both sides of the participant. The average intensity of the presented sounds was set at 75 dB sound pressure level. After establishing a stable baseline on NIRS, we started the recording in each session. We conducted six sessions using the four types of sound files. In the first two sessions, we played the tone file. In one session, participants were asked to listen carefully. In the other session, they were asked not to listen but just to ignore the played file. The third session was intentional listening to a sequence of vowels. The fourth session was also intentional listening to the reverse reading of a meaningful story. In each of the remaining two sessions, we presented a different file of meaningful short stories. Similar to the first two sessions, one was the listening task and the other was the ignoring task. Thus, we measured changes in blood oxygenated hemoglobin in the prefrontal and temporal cortices during various listening and ignoring tasks.

We monitored waves of oxygenated (oxy) and deoxygenated (deoxy) hemoglobin (Hb) by NIRS in the prefrontal and auditory cortices. Examples of the waves are shown in Fig. 1. In general, oxyHb in the temporal cortex increased when subjects listened to sounds or voices, but oxyHb in the prefrontal cortex decreased during many tasks.

2.5. Data analyses

We computed the mean value of oxyHb between 10 and 30 s from the start of each stimulus, and then subtracted the averaged baseline (calculated from data of 10 s before stimuli) to obtain oxyHb changes with the stimuli. Then we calculated averages and standard errors by tasks, attention states, sides and groups (see Fig. 2). We compared the changes of oxyHb using ANOVA by SPSS 19.0.

3. Results

3.1. Cortical response to sounds

First, we compared cortical responses between "listening" and "ignoring" to the same kinds of auditory stimuli. Since the ignoring state was only present in the two tasks of tone and story, we performed a 2 × 2 × 2 mixed randomized-repeated

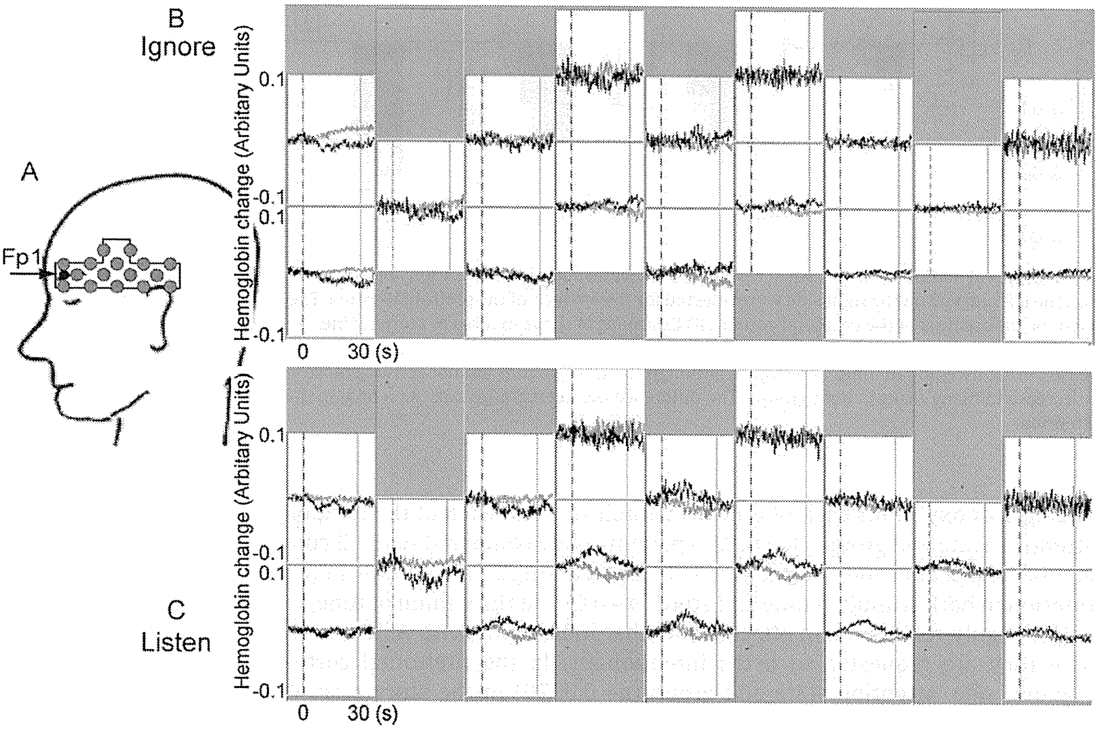

Fig. 1. Examples of the recordings by near-infrared spectroscopy, (A) schematic drawing of recording locations. Gray circles indicate the location of channels. Fp1 in the international 10–20 system was the landmark of the probe setting, shown as a black circle in the figure. This example only shows the responses on the left side of a control subject, but the recordings on the right side were similar. (B) Example of the responses to tones in the ignoring state. Black and gray lines indicate oxyHb and deoxyHb, respectively. Dashed and gray vertical lines indicate the start and the end of the stimuli, respectively. The duration was 30 s. (C) Responses to the same tones in the listening state by the same subject. Temporal areas were activated by tones in the intentional listening state, but not in the ignoring state.

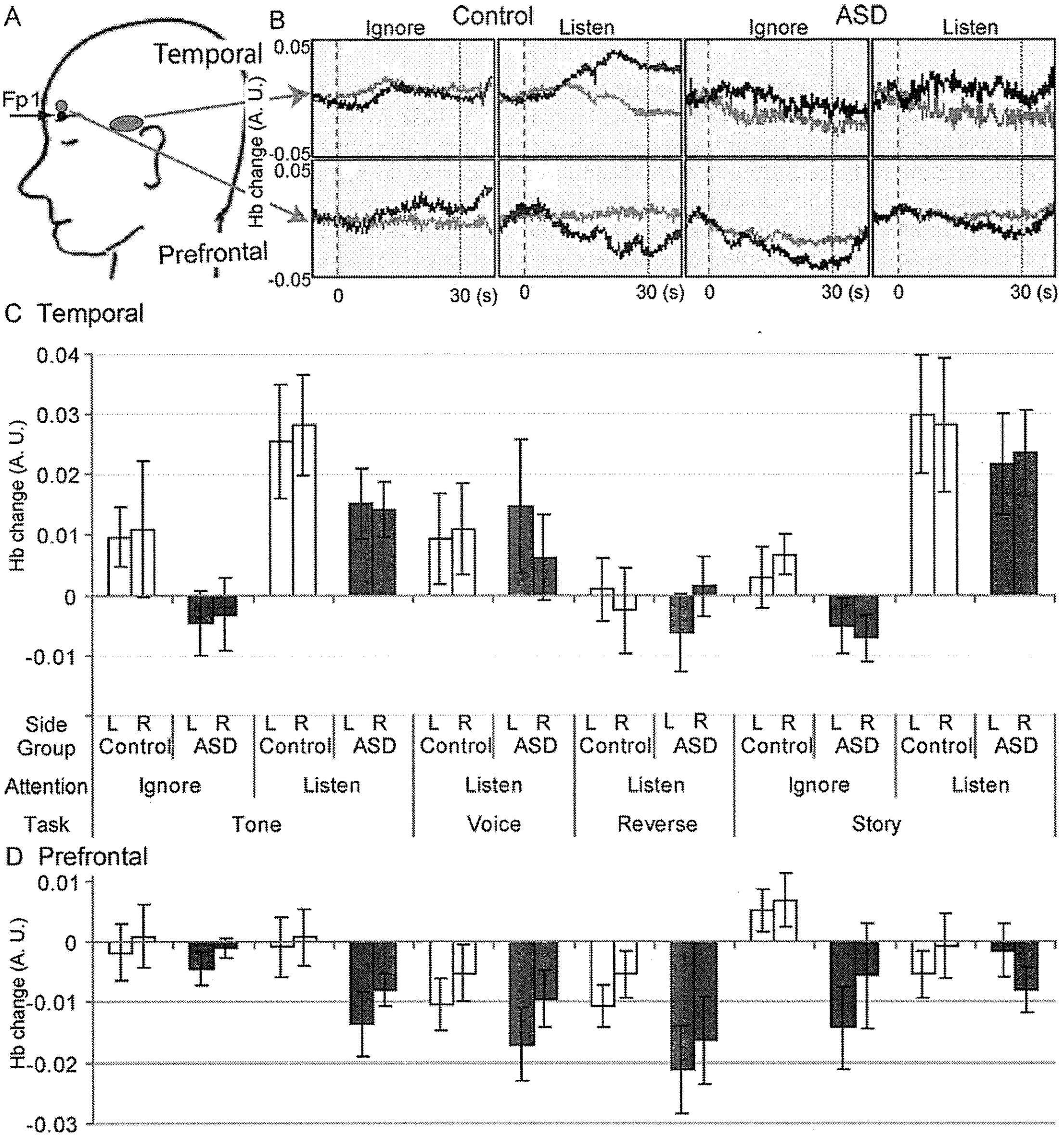

Fig. 2. Analyses of temporal and prefrontal cortical responses to several sounds, (A) locations of the channels used for the analyses. The channels 15 mm above the Fp1 on the left and Fp2 on the right side were selected for the analysis of the prefrontal cortex. The center of the activated channels in the auditory area was selected for the analysis of the temporal cortex. (B) Examples of the responses to stories. Lines are shown as in Fig. 1. (C and D) Responses of the temporal and prefrontal cortices. Bars indicate the averages and error bars indicate the standard errors. Temporal areas in both control and ASD subjects had an oxyHb increase during listening to tones and stories, although the same sounds did not activate those areas in the ignoring state. The prefrontal cortex had an oxyHb decrease in many tasks in both groups. The difference between groups was seen only in the story task. The ASD group showed a laterality switch with attention.

ANOVA on changes of oxyHb for each of the two stimuli sets and each of the temporal and prefrontal cortices. The factors were side, attention state and group. Eleven ASD patients were compared with 12 controls. OxyHb was measured on the left and right sides of each person and when listening to and ignoring sound stimuli. In the temporal cortex, we found only main effects of attention in both stimuli of tone and story ($p = 0.012$ in the stimuli of tone, $p < 0.001$ in the stimuli of story) and no interactions. The highly reliable main effects show that individuals with ASD as well as controls have an apparent oxyHb increase when they are requested to listen intentionally. In the prefrontal cortex, there was a significant three-way interaction among side, attention state and group ($p = 0.0026$) in the story task. We also found a two-way interaction between side and attention state ($p = 0.032$) in this task. Therefore, the interactions were compared separately for the two groups. Only for the ASD group was the interaction statistically reliable ($p = 0.001$), whereas there was no interaction for controls ($p = 0.426$). These results indicate that individuals with ASD might have an abnormal pattern of hemispheric laterality switching when they attempt to regulate their attention to auditory stimuli. However, as the number of participants was small, further investigation is needed on this issue. Neither main effects nor interactions were detected in the tone task in the prefrontal cortex.

We then compared the differences of responses between three pairs of tasks (tone vs. voice, voice vs. reverse, and reverse vs. story) with the intentional listening state. We carried out 2 × 2 × 2 mixed randomized-repeated ANOVAs with the factors of side, task and group. Neither main effects of group nor interactions involving the factor of group were revealed to be significant, indicating that cortical responses to various types of sounds do not differ between ASD and controls as long as they listened intentionally. Although they were not our main focus, the statistical results, which do not involve the factor of group, in these analyses were as follows: We found a significant main effect of stimulus when we compared the stimuli of reverse and story ($p = 0.0013$) without any interaction in the temporal cortex. This main effect indicates that an oxyHb increase in the auditory area is induced when subjects listen to meaningful stories but not to meaningless syllable sequences. There were no main effects or interactions in other comparisons in the temporal cortex. In the prefrontal cortex, in contrast, there were main effects of side, showing a larger oxyHb decrease on the left side, in the comparisons between the two pairs of tone vs. voice ($p = 0.038$) and voice vs. reverse ($p = 0.035$). Also we found an interaction of task and side ($p = 0.040$) when we compared the tasks of reverse and story.

3.2. Recall test

After each of the story sessions, participants were asked to recall the story. We counted the recalled words. Interestingly, individuals with ASD remembered some parts of the story even when they tried to ignore it (Fig. 3). The correctly recalled word numbers were analyzed using a 2 × 2 mixed randomized-repeated ANOVA with the factors of group and attention. We found an interaction between the two factors ($p = 0.012$) and also main effects of attention ($p < 0.001$) and of group ($p = 0.045$). Therefore, we compared group differences separately for the two attention states. When subjects listened intentionally, the number of recalled words did not differ between the two groups ($p = 0.726$). However, when participants were instructed to ignore the story, ASD subjects recalled more words than controls ($p = 0.003$). This result is interesting because the temporal cortex was not activated for persons with ASD subjects in the story-ignoring condition, which is essentially the same as control subjects (see Fig. 2).

4. Discussion

The phenomenon that attention modulates activation in the auditory cortex has been established in healthy subjects (Grady et al., 1997; Jäncke et al., 1999; Petkov et al., 2004; Pugh et al., 1996; Rinne et al., 2007; Woods et al., 2009). We found that it is also the case in autistic subjects. By contrast, previous studies applying a passive listening paradigm in autistic subjects demonstrated hypo-activation of the temporal cortex (Boddaert et al., 2003, 2004; Gervais et al., 2004). The intentional listening condition in our current study appeared to cause the same level of activation of the auditory cortex in ASD as in controls. Thus, the unawareness of autistic participants could be interpreted as due to inattention rather than cortical dysfunction.

Deactivations in the prefrontal cortex are, to a certain extent, general phenomena during various types of cognitive task application. In the studies using NIRS, these phenomena have been reported in the tasks of reading aloud (Fallgatter, Muller,

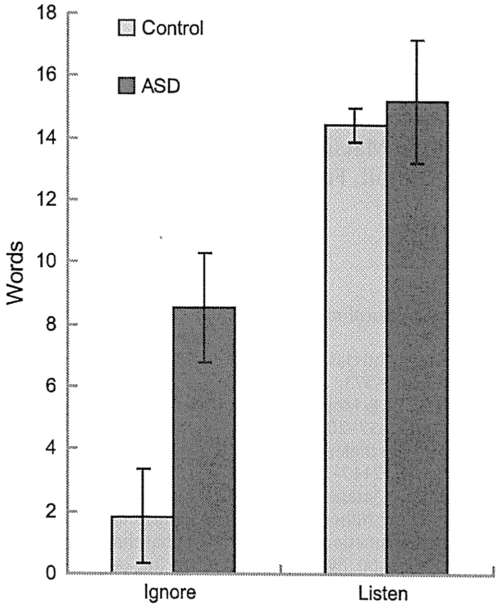

Fig. 3. Word numbers recalled after playback of stories. Each story consisted of 30 words. Bars indicate the averages, and error bars indicate the standard errors. When subjects listened to the story, both groups recalled almost the same number of words. In the ignoring state, controls did not remember the story, but ASD subjects recalled some parts of the story.

& Strik, 1998), reaching (Shimada, Hiraki, Matsuda, & Oda, 2004), and video games (Matsuda & Hiraki, 2006). F-MRI studies have also detected these task-induced deactivations, which are thought to reflect an interruption of mental activities during rest, proposed as the "default mode network" (DMN) (Gusnard & Raichle, 2001; Mayer, Roebroeck, Maurer, & Linden, 2010; Raichle et al., 2001). In autism, deactivation in the default mode network was suggested to be different from controls, although activities in the task-positive network (Fox et al., 2005) and the task performance did not differ (Cherkassky, Kana, Keller, & Just, 2006; Kennedy & Courchesne, 2008; Kennedy, Redcay, & Courchesne, 2006). These findings are compatible with our results, in which the prefrontal cortex showed task-induced deactivation with a different pattern from controls, that is, hemispheric laterality switching of the deactivation during regulating attention to sounds only in ASD, while the auditory area (which is considered to be a major constituent of the task-positive network) and task performance of the word recall during attention did not differ. Furthermore, a recent study showed that motivation normalizes the atypical pattern of the task-related DMN deactivation in attention deficit/hyperactivity disorder (ADHD) (Liddle et al., 2011). Thus, attention might compensate for the attenuated cortical response of the DMN as well as of the auditory cortex in ASD and/or ADHD in our study.

Although we cannot clarify the reason for the increased recalls during the ignoring condition in ASD, difficulties in attention control may account for it. In the listening condition, the equal-level increase of oxyHb in the auditory cortex and also the same level of word recalls in both groups indicate that they followed the instruction. In the ignoring condition, the lack of oxyHb increase in both groups also suggests that they followed the direction. However, ignoring the audible story intentionally was more difficult than intensive listening for persons with autism. That is, even if they tried to ignore the story, which might lead to the lack of oxyHb increase, they might not be able to eliminate the audible story intentionally, resulting in partial memory even without conscious intention. This phenomenon may possibly relate to the hypersensitivity to sounds observed in ASD. The difficulty in regulating attention to sounds in ASD has already been pointed out by an event-related potential study (Ceponiene et al., 2003). Also, a recent behavioral observational study has shown that individuals with ASD often have difficulty paying attention (Funabiki, Kawagishi, Uwatoko, Yoshimura, & Murai, 2011). These reports are in concordance with our results. Furthermore, an electrophysiological study showing that children with autism had left frontal rather than temporal cortical dysfunction is also supportive of our results of cortical response patterns (Gomot et al., 2002).

5. Conclusion

The current study indicates that the auditory cortex in people with ASD responds to sounds and voices as long as the subjects attend to them. The core problem of their apparent unawareness of voices would be explained by hypothesizing the existence of a deficit in regulating attention to voices. In the framework of this hypothesis, the contradictory observation that ASD subjects also show hypersensitivity to sounds is also explainable. We expect that the results of our study will contribute to our understanding of the struggles that ASD patients encounter in their lives, and eventually lead to the reduction of these difficulties through this better understanding by those around them.

Conflict of interest

All authors report no biomedical financial interests or potential conflicts of interest.

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