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Monitoring of self-generated speech in adolescents with 22q11.2 deletion syndrome

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ABSTRACT

Objectives. The present report examines the monitoring of self-generated speech in adolescents with 22q11.2 deletion syndrome (22q11DS), a neurogenetic disorder associated with very high risk for psychosis.

Design. Between-participant group design.

Methods. In this study, 20 adolescents with 22q11DS, 19 age- and IQ-matched controls, and 19 typically developing adolescents were enrolled. Participants completed a speech-monitoring task, in which they were asked to silently or overtly read a series of word and non-word items. Subjects then filled out a recognition sheet containing studied and novel items. They were asked to identify the previously studied item, and to attribute the reading condition (silent vs. overt) under which each recognized item was encoded.

Results. Adolescents with 22q11DS commit more external attribution errors compared to both control groups, by exhibiting an increased tendency to report silently read items as though they had been read overtly. Further, results suggest that increased cognitive effort exacerbates the external attribution tendency in adolescents with 22q11DS. Increased internal attributions were also observed in the IQcontrol and 22q11DS groups in comparison to typically developing adolescents.

Conclusions. Similarly to adult individuals exhibiting positive symptoms of psychosis, adolescents with 22q11DS exhibit an external attribution bias for inner speech. This bias seems to be exacerbated by increased cognitive effort, suggesting a failure to recollect information pertaining to cognitive operations during self-monitoring. Cognitive biases associated to schizophrenia may be detected in adolescents at very high risk for psychosis. These observations provide further evidence for the presence of an external attribution bias along the clinical continuum of psychosis vulnerability.

Current perspectives in cognitive psychopathology describe how faulty monitoring of one's inner speech may contribute to aberrant perceptual experiences such as auditory hallucinations (Allen *et al.*, 2007; Frith, 1992). Indeed, several observations suggest that inner speech is intimately tied to the phenomena of auditory hallucinations. For instance, the timing and content of the hallucinatory experience in schizophrenic patients often coincide with subvocalizations (Green & Preston, 1981).

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The monitoring of inner speech, which represents one instance of internal or self monitoring, consists in attributing the origin of internally generated material (Johnson, Hashtroudi, & Lindsay, 1993). It necessitates efficient discrimination between one's personal thought, dreams, or past verbalizations. In extreme cases, 'misattributed' inner speech may be experienced as originating from a source external to the self, which could critically contribute to the experience of verbal auditory hallucinations. Several studies on speech monitoring in schizophrenia provide evidence pointing to faulty monitoring of intended speech (Cahill, 1996; Johns et *al.*, 2001), misidentification of one's personal voice (Allen et al., 2004), and memory confusions in discriminating silent and overt reading (Franck et al., 2000). These studies all provide evidence towards flawed self-monitoring in individuals with schizophrenia. A recent report also suggests that misattributions of self-generated speech can occur in healthy adults with increased proneness to psychotic-like experiences (Allen, Freeman, Johns, & McGuire, 2006). While these studies involve adults within or beyond the critical period of the first episode of psychosis, information on the monitoring of self-generated speech in adolescents at increased-risk for schizophrenia is lacking. As Bentall, Fernyhough, Morrison, Lewis, and Corcoran (2007) recently argue, there may be interesting prospects for the elaboration of a cognitive-developmental account of psychotic experiences by applying self-monitoring research methods to children and adolescents at high risk for psychosis (Bentall et al., 2007). In the present report, we propose the examination of selfgenerated speech monitoring in adolescents with 22q11.2 deletion syndrome (22q11DS), a neurogenetic condition leading to very high risk for schizophrenia.

Individuals with 22q11DS are at very high risk for developing schizophrenia (Murphy, 2005). Verbal auditory hallucinations can appear early in the development of children with 22q11DS (Debbané, Glaser, David, Feinstein, & Eliez, 2006). By their late teens, approximately half of adolescents with 22q11DS report schizotypal manifestations (Baker & Skuse, 2005), and during adulthood, almost a third of affected adults will meet the diagnostic criteria for schizophrenia (Murphy, Jones, & Owen, 1999). Also known as velo-cardio-facial syndrome (VCFS), 22q11DS most commonly results from a congenital deletion on chromosome 22 (Scambler et al., 1992), and affects approximately 1 in 4,300-7,000 live births (Oskarsdottir, Vujic, & Fasth, 2004). Recent studies suggest that a decline in verbal competencies accompany the unfolding of psychotic symptoms in adolescents with 22q11DS (Debbané et al., 2006; Gothelf et al., 2005). However, the cognitive processes relating to psychotic symptom expression have yet to be examined in 22q11DS. Studying self-monitoring skills in high risk for psychosis adolescents *before* they enter the critical period of schizophrenic unfolding may provide significant information on the type of cognitive processes that set the stage for increased vulnerability to psychosis during adulthood in this syndrome.

The symptoms associated to schizophrenia, namely the positive symptoms of delusions and hallucinations, may be associated with self-monitoring skills (Allen *et al.,* 2007; Brébion, Gorman, Amador, Malaspina, & Sharif, 2002; Brunelin et al., 2007). In a study examining self-monitoring for internal and external speech, Franck et *al.* (2000) asked participants with schizophrenia and healthy controls to memorize a list of words by having them read the items either silently (thought) or overtly (spoken). After a 5-min interval, subjects were presented with a recognition list including the studied items together with new items, and were asked to categorize each item accordingly with the encoding procedure as *thought, spoken,* or *absent.* In comparison to controls, patients showed reduced recognition rates of studied *thought* and *absent* words, and showed increased external

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confusions, which consisted in reporting as *spoken* word items that had been learned as *thought* words (thought-spoken inversion). In the self-monitoring literature, this type of confusion, termed as an *external attribution bias* (Baker & Morrison, 1998; Bentall, Baker, & Havers, 1991; Keefe, Arnold, Bayen, McEvoy, & Wilson, 2002), consists in attributing self-generated material to an exterior source, or in this case, to a source external to the self. While external attribution biases may vary according to intensity of positive symptom expression (Allen *et al.*, 2004), or according to the state of the psychotic vulnerability (Brunelin *et al.,* 2007), and to meta-cognitions about personal thought processes (Morrison & Haddock, 1997), examples of external attributions biases are also reported in stabilized schizophrenic patients (Vinogradov *et al.*, 1997), as well as in studies involving healthy individuals with increased hallucination proneness (Larpi, Collignon, & Van der Linden, 2005; Larpi, Van der Linden, & Marczewski, 2004). Therefore, specific self-monitoring biases do not appear to be strictly dependant on symptom manifestation, but rather, they can be observed along the continuum of psychosis.

The examination of self-monitoring processes in a source-monitoring framework (Johnson *et al.,* 1993) describes how the identification of self-related information relies on the contextual information that uniquely characterizes a mental event. Among these contextual elements, the *cognitive effort* engaged during the unfolding of a mental event promotes self-monitoring efficiency (Finke, Johnson, & Shyi, 1988). Indeed, cognitive effort during encoding enrols cognitive operations which become part of the recorded episode. This supplementary cognitive activity later constitutes distinct recollection material, which will assist and promote efficient monitoring (Dewhurst & Hitch, 1999). Interestingly, source-monitoring performances in schizophrenic patients appear to be penalized in high cognitive effort conditions (Bentall *et al.*, 1991). Patients with auditory hallucinations make more source misattributions on items requiring increased cognitive effort. More specifically, the external attribution bias observed in patients with schizophrenia seems to be exacerbated in high cognitive effort conditions. It may be that increased cognitive loading does not contribute to the distinctiveness of an episode but rather, overload individuals with schizophrenia, leaving their characteristic biases (external attributions) unchecked.

In the present study, we examine self-generated speech monitoring in adolescents with 22q11DS, a group at very high risk for developing schizophrenia. Using a speech-monitoring task inspired from Franck *et al.* (2000), we assess self-monitoring of silent and overt speech in youngsters with 22q11DS. We wish to examine whether specific external attribution patterns, such as those observed in high risk and schizophrenic adult populations, also appear in adolescents with 22q11DS. Given the below-average intellectual profile associated with this syndrome, we included comparison participants matched for intellectual quotient and age, as well as another group of typically developing control adolescents. Firstly, we hypothesized that adolescents with 22q11DS would exhibit self-monitoring deficits, by showing higher rates of source confusions when discriminating between self-produced internal and external speech. Second, we hypothesized that adolescents with 22q11DS, who are at very high risk for schizophrenia, would exhibit a specific external attribution bias, characterized by an increased tendency to recollect silent speech as overtly performed speech. We also cared to examine the influence of cognitive effort on silent speech-monitoring efficiency. Thus, the inclusion of words and non-words in our reading task was designed to manipulate cognitive effort, in which low (word condition) and high (non-word condition)

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cognitive effort conditions could be compared. We hypothesized that adolescents would also exhibit higher rates of external misattributions in high cognitive effort conditions, thereby illustrating the exacerbation of an external attribution bias under cognitively difficult conditions. Finally, we examined whether linear relationships could be established between self-monitoring deficits and symptom dimensions of positive schizotypy, anxiety, or depression in adolescents participants from our sample.

Method

PARTICIPANTS

In this study, 20 participants with 22q11DS (22q group), 19 age- and IQ-matched controls (IQcontrol group), and 19 typically developing controls (TYPcontrol group) were enrolled. Participants with 22q11DS *(F* = 15, *M* = 5; mean age = 13.97 ± 1.27) were recruited through announcements in parent association newsletters and by word of mouth. All members of the IQcontrol (F = 11, M = 8; mean age = 15.07 ± 1.52) group were recruited through a community psychiatric service child and adolescent for children and adolescents (Service Medico-Pédagogique) affiliated to the University of Geneva's Psychiatry Department and to the Canton of Geneva Education Department. All members of the TYPcontrol group (F = 13, M = 6; mean age = 15.33 ± 1.75) were screened for neurological and psychiatric disorders. They were recruited through a newsletter distributed at public schools and in the community near the research centre. Written informed consent was received from participants and their parents under protocols approved by the Institutional Review Board of the Department of Psychiatry of the University of Geneva Medical School. All participants underwent an intellectual evaluation, using the Wechsler Intelligence Scale for children (WISC-III) short-form (Kaufman, Kaufman, Balgopal, & McLean, 1996). Using age appropriate self-report instruments, all participants were screened for levels of anxiety *(Revised Children's Manifest Anxiety Scale (R-CMAS),* Turgeon & Chartrand, 2003), and depression *(Children's Depression Inventory (CDI),* Saint-Laurent, 1990).

In order to assess psychotic symptoms and their dimensions, subjects individually filled out the Schizotypal Personality Questionnaire (SPQ; Raine, 1991): translation and validation into French (Dumas *et al.*, 2000). The instrument yields three main factor scores (cognitive-perceptual, interpersonal, and disorganization) and nine subscale scores (ideas of reference, social anxiety, odd beliefs/magical thinking, unusual perceptual experiences, eccentric/odd behaviour and appearance, no close friends, odd speech, constricted affect, suspiciousness/paranoid ideation). It also lends itself to multiple dimensional analyses in the context of a dimensional approach to schizotypy (Rossi & Daneluzzo, 2002), is appropriate for usage with adolescents (Axelrod, Grilo, Sanislow, & McGlashan, 2001). Personal characteristics of each group are included in Table 1.

MATERIALS

Self-monitoring task

Our self-monitoring task was inspired from Franck *et al.* (2000), who examined speech monitoring in a group of schizophrenic individuals. The present self-monitoring task asked subjects to read a series of words and non-words, either silently or overtly. We introduced modifications to the Franck et *al.* study by increasing the total number of items and including two levels of cognitive effort, with

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half of the items presented as familiar words (low cognitive effort) and half presented as non-words (high cognitive effort). Therefore, our self-monitoring paradigm was construed as a 2 X 2 experimental design, with reading condition (silent vs. overt) and cognitive effort (low vs. high) as dependant variables, and group as independent variable. These modifications were introduced to increase sensitivity to the precise conditions under which self-monitoring confusions could occur in adolescents at high risk for psychosis. Specifically, the performance on silently read words and non-words were combined to examine external attribution bias, and then contrasted to evaluate the effect of cognitive effort on this bias.

Table I. *Group descriptive measures of age, intellectual evaluation, and self-questionnaire scores*

	22qllDS group (N = 20)[a]	IQcontrol group (*N* =19)	TYPcontrol group (*N* = 19)
FSIQ estimate[b]	79.12 ± 12.65*	85.64 ± 11.93*	105.88 ± 8.24
R-CMAS total score percentile	70.40 ± 25.42	79.32 ± 22.41*	61.32 ± 30.07
CDI *t* score	51.45 ± 8.51*	57.16 ± 11.81*	45.26 ± 6.29
SPQ total score	21.15 ± 11.00*	23.95 ± 10.27*	14.16 ± 9.78
Cognitive-perceptual	7.25 ± 5.49	10.32 ± 5.95*	5.63 ± 4.69
Interpersonal	9.00 ± 3.85*	7.95 ± 4.02	5.42 ± 4.22
Disorganization	4.90 ± 3.23	5.68 ± 4.27	3.11 ± 2.45

[a] 22q11DS and IQcontrol groups do not significantly differ on any descriptive measure.

[b] Estimate derived from recommended WISC-III short form by Kaufman et al. (1996), which includes Similarities, Arithmetic, Picture Completion, and Block Design subtests.

**p < .05 on group comparisons with TYPcontrols.*

This task was presented as a reading and pronunciation exercise. The participants were given the following instructions: 'On this screen, you will be presented with a series of words and non-words. I want you to read them carefully. You will be asked to read some of them out loud, and others silently. For every word, you must pay special attention to your pronunciation, even when you read them silently'. The participant was presented with six blocks (six silent, six overt) of eight items (eight words, eight non-words), alternating between silent and overt conditions. Within the blocks, the word and non-word items were randomly presented. Before each block, a written instruction prompted the participant to read the items either silently or overtly. In total, each condition contained 12 items, for a total of 48 items (12 word/overt items, 12 word/silent items, 12 non-word/overt items, 12 non-word/silent items). After a 10-15 min visuospatial filler task, the recognition phase was introduced by a brief summary of the study phase, reminding the participant of the two conditions in which the word and non-word items were encoded. A recognition sheet was then handed out, containing 72 items (12 read words, 12 read non-words, 12 silent words, 12 silent non-words, 12 new words, and 12 new non-words). The participant had to recognize whether the items belonged to the study phase (recognition test), and for each recognized item, to attribute the

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reading condition (silent vs. overt).

During the procedure, subjects were seated 60 cm away, in front of a computer screen. Stimuli presentation was managed by Eprime software, and all items appeared in black letters on white screen (Courier New font; Point Size 18). A total of 72 words with comparable frequency and usage in the French language (Brulex) were first selected. Half of these words were used as word items, and the other half were used as source for non-word items. Item letter-length (consonant = c, vowel = v) was four (c-v-c-v; 24 items), five (c-v-c-v-c; 24 items), or six letters (c-v-c-v-c-v; 24 items). Non-words were generated according to the following procedure: for c-v-c-v items, the syllables were inversed; for c-v-c-v-c items, the last two consonants were inversed; for c-v-c- v-c-v, the first two syllables were inversed (see Appendix). The final blocks (12 read words, 12 read non-words, 12 silent words, 12 silent non-words, 12 new words, and 12 new non-words) were each composed of 4 c-v-c-v items, 4 c-v-c-v-c items, and 4 c-v-c-v-c-v items.

STATISTICAL ANALYSES

Group comparisons of clinical measures were performed using a 3 (R-CMAS total percentile score, CDI *t* score, SPQ total score) X 3 (groups) multivariate analysis of variance (MANOVA) with *post hoc* comparisons using the Fisher least significant difference. On the schizotypy measure, separate one-way analyses of variance (ANOVA) examined potential group differences on the cognitive-perceptual, interpersonal, and disorganization factors. Following our hypotheses on self-monitoring performances, separate one-way ANOVAs first examined group differences for global performance scores on correct recognitions (Hits), false recognitions, and ratio of source confusions (percentage of total confusions on total correct recognitions). Second, a MANOVA was employed to examine group differences on external and internal confusions. Specifically, percentage of external misattributions (total number of silent-items reported as overt items, divided by number of correct recognitions of silent items) and percentage of internal misattribution (total number of overt-items reported as silent items, divided by number of correct recognitions of overt items) were employed. Therefore, a 2 (percentage external misattribution, percentage internal misattribution) X 3 (groups) MANOVA was performed, followed by *post hoc* comparisons using Tukey's correction to identify specific group intergroup differences. Third, a repeated measures ANOVAs was performed to assess the influence of cognitive effort on external misattribution errors. To allow these comparisons, two external attributions ratios were computed as follows: silent words recalled as overt words versus silent non-words recalled as overt non-words (the ratios were divided by individual score of correct recognitions for silent words and silent non-words, respectively). Finally, follow-up correlations were performed to identify any possible relationship between psychological variables (R-CMAS total percentile score, CDI t score, SPQ total score, and SPQ cognitive-perceptual score) and significant group differences on source-monitoring performance scores.

Results

The MANOVA examined group differences on clinical measures and found statistically significant group differences as indicated by Wilk's A (.75), $F(3, 55) = 2.75$, $p < .02$. Results from individuals group contrasts on group measures are reported in Table 1. The 22q11DS group and IQcontrol group do not differ on any clinical measure:

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One-way ANOVAs for Hits, $F(3,55) = 0.36$, $p = .70$), and false alarms, $F(3, 55) = 0.34$, $p = .71$, did not yield any significant differences. However, the oneway ANOVA for percentage of total confusions yielded significance, $F(3, 55) = 4.02$, $p < .03$. Follow-up Tukey's Honestly Significant Differences (HSD) pairwise tests revealed that the 22q11DS group made significantly more source confusions compared to TYPcontrols ($p < .02$). Second, the MANOVA examining group differences for external and internal monitoring confusions revealed statistically significant group differences as indicated by Wilk's A (.78), F(3, 55) = 1.12, $p < .04$. Follow-up Tukey HSD pairwise tests revealed that the 22q11DS group made significantly more external confusions compared to both the IQcontrol group ($p < .03$) and to the TYPcontrol group ($p < .02$). Both the 22q11DS group and the IQ control group made more internal confusions compared to the TYPcontrol group ($p < .04$, and $p < .02$, respectively). Performance scores are presented in Table 2.

Table 2. *Group performances on the speech-monitoring task*

	22q11DS group ($N = 20$)	IQcontrol group ($N = 19$)	TYPcontrol group ($N = 19$)
Total Hits	31.45 ± 6.86	32.58 ± 6.36	33.16 ± 5.83
Total false recognitions	5.05 ± 4.15	5.74 ± 3.02	4.89 ± 2.66
Percentage total confusions	38.93 ± 2.60*	34.85 ± 2.66	28.41 ± 2.66
Self-monitoring error ratios (%)			
External confusions ratio	40.45 ± 15.07**	30.36 ± 13.78	29.14 ± 13.53
Internal confusions ratio	37.38 ± 14.70*	39.02 ± 14.06*	27.83 ± 13.24
Condition specific confusions (%)			
Word external confusions	33.10 ± 24.73	33.17 ± 20.47	29.89 ± 18.51
Non-word external confusions	48.28 ± 16.85**	25.81 ± 19.53	28.71 ± 15.15
Word internal confusions	38.28 ± 20.94	35.64 ± 18.46	23.92 ± 20.73
Non-word internal confusions	35.58 ± 20.74	44.08 ± 21.73	32.88 ± 20.75

**p < .05 on group comparisons with TYPcontrols only; **p < .05 on group comparisons with both IQcontrols and TYPcontrols.*

The 2 (silent word errors, silent non-word errors) X 3 (group) repeated measures ANOVA for external attribution errors revealed no significant effect for effort condition, $F(3, 55) = 0.34$, $p = .564$), but a significant group X effort condition interaction, $F(3, 55) = 3.53$, $p < .04$). Follow-up Tukey HSD pairwise tests revealed significant group contrasts for 22q11DS and IQcontrols ($p < .04$), and for 22q11DS and TYPcontrols ($p < .04$), suggesting that external misattributions increased with cognitive effort for individuals with 22q11DS when compared to both control groups (Figure 1).

Finally, follow-up Pearson correlations were performed to examine whether selfmonitoring external misattribution ratio in the 22q11DS group (ratio of silent non-words recognized as overt) were related to age, IQ, or measures of psychological dimensions. No significant relationships were found between self-monitoring errors and age ($r = .361$, $p = .12$), IQ ($r = -.271$, $p = .25$), total SPQ ($r = -.15$, $p =$

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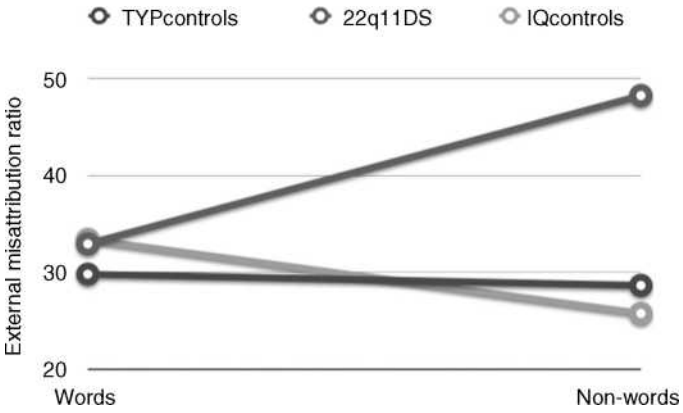
.53), SPQ cognitive-perceptual subscale *(r* = -.25, *p* = .29), R-CMAS total *t* score *(r* = .003, *p* = .99), CDI total t score (*r* = .09, *p* = .71).

Discussion

Speech-monitoring performances examined in this study suggest impaired self-monitoring mechanisms in adolescents with 22q11DS. Compared to typically developing controls, adolescents from both the 22q11DS group and the IQcontrol group exhibit increased internal attribution errors, by remembering overtly read items as items read silently. We will discuss this issue in light of the clinical features shared by both groups. The present results also suggest that in comparison to both IQcontrol and TYPcontrol groups, the 22q11DS group demonstrate an external attribution bias for selfgenerated silent speech, that is, they exhibit an increased tendency to recollect silently read items as though they had been read overtly. Closer examination revealed that the high cognitive effort condition yielded a strong external attribution bias for adolescents with 22q11DS. These results will be discussed in light of previous literature on self-monitoring performances in hallucination-prone adults and adults with schizophrenia.

Figure I. *Group averages of external misattributions percentage in low cognitive effort (word) and high cognitive effort (non-word) conditions.*



The internal attribution bias found in both the IQcontrol group and the 22q11DS group was not expected. The fact that both groups are cognitively impaired may have contributed to the differences between their performances and that of TYPcontrols. However, children with autism and children with mental retardation demonstrate no such internal attribution bias compared to healthy control children (Farrant, Blades, & Boucher, 1998). Alternatively, the groups' increased scores on the depression scale may point to another factor associated to the internal attribution bias. Indeed, previous literature suggests that depressed individuals display a preferential bias for self-related information (Taylor & John, 2004). Additionally, delusions may constitute a further symptomatic element associated to an internal attribution bias in these groups. Recent studies suggest that internalizing attribution biases contribute to the source discrimination deficit in schizophrenia (Moritz & Woodward, 2006; Woodward, Menon, Hu, & Keefe, 2006). Indeed, delusions may represent an index of increased self-referential thinking (Freeman, Garety, & Phillips, 2000), and may be

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associated to internal attribution biases during adolescent maturation. Nevertheless, we must remain prudent in our interpretation, since these results are the first to suggest internal attribution bias for self-generated content. Further research may address this issue, by including tools specifically designed to characterize delusions in adolescents, and paradigms exploring attribution biases of self- and non-self-generated content.

Focusing on the performances from adolescents with 22q11DS reveals intact recognition skills, but broad self-monitoring deficiencies. External attributions, or the increased tendency to misattribute silently read items as having been read overtly, are more frequent in teens with the syndrome when compared to both control groups. These results are consistent with previous studies in many respects. First, they suggest that verbal item-recognition memory is relatively unimpaired in 22q11DS (Debbane, Glaser, & Eliez, 2008). Second, much like hallucination-prone individuals (Larpi *et al.*, 2005) and individuals with schizophrenia (Franck et al., 2000) performing self-monitoring tasks, adolescents with 22q11DS exhibit an external attribution bias for selfgenerated material. Therefore, adolescents with 22q11DS exhibit cognitive alterations that are consistent with those observed along the continuum for psychosis (Brunelin et *al.*, 2007; Larpi et *al.*, 2004). To the best of our knowledge, this study also represents the first evidence of an external attribution bias in an adolescent sample at high risk for psychosis. As such, these results provide further support to the notion of early cognitive markers signalling increased vulnerability to schizophrenia during adolescence.

Although self-monitoring deficits may be present at an early stage in adolescents at high risk for schizophrenia, the present results fail to illustrate a linear relationship between self-monitoring deficits and schizotypal symptoms such as magical thinking, delusional thought, or unusual perceptual experiences. While this may seem surprising, it must be noted that most self- or source-monitoring studies in schizophrenia seldom report significant correlations between symptom intensity and source-monitoring deficits, but rather, present significant groups comparisons, which illustrate greater monitoring deficits in symptomatic participants (Baker & Morrison, 1998; Brébion *et al.,* 2002; Vinogradov et al., 1997). The absence of any correlation between positive symptoms of schizotypy and external attributions in the speech-monitoring task may also be due to methodological factors. Indeed, studies reporting external attribution biases on source-monitoring paradigms focus on *hallucination* proneness and manifestations in their sampling strategy (Brébion et al., 2000; Brunelin et al., 2006), yielding groups that might be more homogeneous in terms of clinical profiles. In our study, we employed the SPQ subscale scores, which yield heterogeneous indexes combining delusional ideations and unusual perceptual experiences of different kinds. Therefore, the inclusion of tools specifically examining hallucinations may yield closer relationships to external attribution biases in high risk adolescents. This point may be of particular interest when considering the IQcontrols on the self-monitoring paradigm, who exhibited increased schizotypy scores in comparison to the TYPcontrol group, yet did not show increased external attributions. Close examination of the SPQ items specifically targeting hallucinations reveals that 38% of the IQcontrols caution at least one hallucination item on the SPQ, whereas as 50% of the 22q11DS group report having experienced hallucinations. While comparisons of self-report questionnaire items must be interpreted with caution, they underscore the importance of sensitivity to hallucinations in research designs examining the relationships between self-monitoring and psychotic symptoms.

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Our results further suggest that cognitive effort contributes to the external attribution bias in adolescents with 22q11DS. Indeed, the syndrome group displayed more frequent external misattributions in the high cognitive effort condition involving silently read non-words. This is consistent with studies involving hallucination-prone adults (Larpi *et al.*, 2004) and patients with schizophrenia (Bentall *et al.*, 1991), who also report increased external attribution errors for high cognitive effort items. These investigators suggest that the failure to employ the available information triggered by increased cognitive effort underlies source-monitoring deficits in individuals experiencing hallucinations. We further suggest that during self-monitoring performances, it is *personal* information, or cognitive operations involving the self that are not appropriately accessed to favour efficient retrieval. This phenomenon ties in with the concept of *autonoetic* agnosia, or the inability to correctly identify self-generated information (Keefe, Arnold, Bayen, & Harvey, 1999), which many authors regard as the central memory deficit in schizophrenia (Danion, Rizzo, & Bruant, 1999; Keefe *et al.,* 2002). The question remains, however, to determine why some attributions would be externalized, and others internalized. As we suggest above, self-referential thinking style observed in delusional patients may be associated to internalization biases in memory performances. Concerning the externalization biases, several authors propose that beliefs about our own thought processes, or meta-cognitions, play an important role in the external attribution of self-generated content (Baker & Morrison, 1998; Lobban, Haddock, Kinderman, & Wells, 2002). Specifically, errors of external attribution in hallucination-prone adults directly correlate with the extent to which they entertain poor self-confidence in their cognitive capacities and positive beliefs about worrying (Larpi *et al.,* 2005). It is hypothesized that the external attribution of conflicting content reduces the cognitive dissonance that can provoke certain intrusive thoughts clashing with the individual's belief system (Morrison, Haddock, & Tarrier, 1995). This meta-cognitive process may be involved in the development of auditory hallucinations; we may also hypothesize that it represents a potential thinking style with which hallucination-prone individuals maintain consistency in their belief system. Consequently and as observed in recent studies, external attributions can affect non-intrusive content, and may represent an index of hallucination-proneness potentially identifiable during adolescence.

In conclusion, adolescents with 22q11DS exhibit impaired self-monitoring skills. They show an external attribution bias that significantly differs from both the IQcontrol and TYPcontrol groups. There are methodological limitations to this study, in particular the lack of instruments that could specifically characterize delusions, hallucinations and meta-cognitions in the adolescent groups. The results point to the heterogeneity in clinical profiles and self-monitoring performances between groups, and suggest finer assessments of the potential relationships between symptoms of delusions and/or hallucinations and self-monitoring biases. In adolescents with 22q11DS, longitudinal studies are necessary to evaluate the extent to which the attribution biases for speech monitoring contribute to the evolution of clinical psychotic manifestations. Potentially, an external attribution bias for self-generated speech may represent a constituent process in the unfolding of psychosis-proneness and/or further development of a psychotic illness in 22q11DS. In turn, self-monitoring skills may represent preventive treatment targets in adolescents who are at very high genetic-risk for the development of schizophrenia. Future studies must account for the factors such as cognitive effort and meta-cognitions in their assessment of the cognitive processes setting the

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stage for psychotic symptoms.

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Appendix

Words	Non-words	Non-word source
c-v-c-v		
cage	leca	cale
cave	pypa	Papy
date	daso	soda
dire	seva	vase
gare	cevi	vice
mode	becu	cube
note	seru	Ruse
page	**peju**	**jupe**
vide	**tolo**	**Loto**
lire	**Tevo**	**vote**
rare	**Lijo**	**joli**
lune	**Tevi**	**vite**
c–v–c–v–c		
filer	**Fitel**	**filet**
future	**Tacab**	**tabac**
gamin	**Ciliv**	**civil**
hiver	**manir**	**Marin**
lapin	**Bunit**	**butin**
laver	**dinav**	**Divan**
jeter	**binal**	**Bilan**
mener	**valet**	**Valet**
repas	**satul**	**Salut**
repos	**senol**	**Selon**
salon	**terin**	**Tirer**
finir	**furem**	**Fumer**
c–v–c–v–c–v		
cabine	**migane**	**Gamine**
nature	**lupile**	**Pilule**

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navire	**valage**	**Lavage**
balade	**rimane**	**Marine**
pilote	**luvome**	**Volume**
rapide	**rapade**	**Parade**
refuge	**nafile**	**Finale**
visite	**cirane**	**racine**
samedi	**nabane**	**banane**
valise	**gacire**	**cigare**
facile	**necima**	**cinéma**
copine	**gadege**	**dégage**