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Abstract

Children often talk themselves through their activities: They produce private speech to regulate their thought and behaviour, which is internalised to form inner speech, or silent verbal thought. Private speech and inner speech can together be referred to as *self-directed speech* (SDS). SDS is thought to be an important aspect of human cognition. The first chapter of the present thesis explores the theoretical background of research on SDS, and brings the reader up-to-date with current debates in this research area. Chapter 2 consists of empirical work that used the observation of private speech in combination with the dual task paradigm to assess the extent to which the executive function of *planning* is reliant on SDS in typically developing 7- to 11-year-olds. Chapters 3 and 4 describe studies investigating the SDS of two groups of atypically developing children who show risk factors for SDS impairment—those with autism and those with specific language impairment. The research reported in Chapter 5 tests an important tenet of neoVygotskian theory—that the development of SDS development is *domain-general*—by looking at cross-task correlations between measures of private speech production in typically developing children. Other psychometric properties of private speech production (longitudinal stability and cross-context consistency) were also investigated. Chapter 6, the General Discussion, first summarises the main body of the thesis, and then goes on to discuss next steps for this research area, in terms of the methods used to study SDS, the issue of domain-general development, and the investigation of SDS in developmental disorders.

**Private Speech and Inner Speech
in Typical and Atypical Development**

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2010

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Publications included in this thesis

Chapter 2

Lidstone, J. S. M., Meins, E., & Fernyhough, C. (2010) *The roles of private speech and inner speech in planning in middle childhood: Evidence from a dual task paradigm*, 107, 438-451.

Chapter 3

Lidstone, J. S. M., Fernyhough, C., Meins, E., & Whitehouse, A. J. O. (2009). Brief report: Inner speech impairment in children with autism is associated with greater nonverbal than verbal skills. *Journal of Autism and Developmental Disorders*, 39, 1222-1225.

Chapter 4

Lidstone, J. S. M., Meins, E., & Fernyhough, C. (2010). *Verbal mediation of cognition in children with specific language impairment*. Manuscript submitted for publication.

Chapter 5

Lidstone, J. S. M., Meins, E., & Fernyhough, C. (2010). *Cross-task consistency, longitudinal stability, and cross-context consistency of individual differences in private speech production in middle childhood*. Manuscript submitted for publication.

Declaration

The research contained in this thesis was carried out by the author between 2007 and 2010 while a postgraduate student in the Department of Psychology at Durham University. None of the work contained in this thesis has been submitted in candidature for any other degree. The empirical work of Chapter 3 is based on data collected by Andrew Whitehouse of the University of Western Australia.

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General Introduction

1.1 Introduction

A 7-year-old boy attempts a puzzle in the presence of an experimenter.

“Oh, what?” he says. “An arrow? ... A yellow one. Haven’t enough. Yes! Got another one. [Inaudible.] There!”

This is what developmental psychologists call *private speech*, formerly *egocentric speech*. How should we characterise these utterances? Do they constitute an only partially successful attempt to communicate with the experimenter? An indirect appeal for help? Perhaps this little boy is simply doing his puzzle in the manner in which he does everything else: noisily. Or perhaps his speech is an instrumental part of his problem-solving behaviour. Whatever this speech represents, can we learn anything about the cognition of the child, or indeed that of the adult, by studying it?

In this chapter I will give a brief account of the origins of work on private speech, and will then describe its subsequent evolution, in order to justify current views on private speech, as well as to describe how they were formulated over time.

1.2 Theoretical background

1.2.1 Piaget

In a study of the language of the child, Piaget (1923/1926) recorded the speech of two 6-year-olds at school over a period of a month. The classroom context was the children’s activities and their social context (individual play, in pairs, or in

groups) were of their own choosing. Having recorded a corpus of 1400 utterances for each child, Piaget proceeded to classify the functions of the utterances. He distinguished between utterances that were *egocentric* and those that were *socialised*. Socialised utterances were those whose content was adapted to the needs of the listener, and those that were part of a social interaction. In contrast:

When a child utters phrases belonging to the [egocentric category], he does not bother to know to whom he is speaking nor whether he is being listened to. He talks either for himself or for the pleasure of associating anyone who happens to be there with the activity of the moment. *This talk is ego-centric, partly because the child speaks only about himself, but chiefly because he does not attempt to place himself at the point of view of the hearer.* Anyone who happens to be there will serve as an audience. The child asks for no more than an apparent interest, though he has the *illusion* (except perhaps in pure soliloquy if even then) *of being heard and understood.* He feels no desire to influence his hearer nor to tell him anything; not unlike a certain type of drawing-room conversation where everyone talks about himself and no one listens (Piaget, 1923/1926, p. 9, emphasis added).

Egocentric speech included three subcategories: repetition, monologue and collective monologue. The first was a child's repetition of words and syllables "for the pleasure of talking, with no thought of talking to anyone, nor even at times of saying words that will make sense" (p. 9). Monologue was speech that had no audience, serving only to "accompany, to reinforce, or to supplement" the child's action (p. 17). Collective monologue was monologue that was performed before

others, who are “supposed to be listening” (p. 19) but who are not the true audience in the mind of the child, who is simply “thinking his actions aloud, with no desire to give anyone any information about it” (p. 19).

Egocentric speech constituted 37% and 39% of the two participants’ utterances respectively. The abundance of egocentric speech was, to Piaget, a symptom of the children’s egocentric thought, which represented an intermediate stage between the less mature *autistic* or undirected thought, and the more mature *rational* or directed thought. Rational thought at the time was said to be defined by four properties: (a) It is conscious, in that its aim is present in consciousness; (b) It is intelligent, in that it is adapted to reality or tries to influence it; (c) It “tends to establish truths” and therefore can be correct or incorrect; and (d) It can be communicated by language. This contrasts with autistic thought, which was said to be subconscious, in that its aims are not present in consciousness, and unintelligent, in that it is not adapted to reality, “creating for itself a dream world of imagination” instead (p. 43); autistic thought tends towards satisfying desires rather than establishing truths, and it is incommunicable by means of language, being represented primarily in images instead. According to Piaget, intermediate both conceptually and developmentally between autistic and rational thought is egocentric thought: “the type of thought ... that seeks to adapt itself to reality, but does not communicate itself as such” (p. 45).

Although speech was said by Piaget not to have a cognitive function that can be separated from its social function, it does appear that he attributed a role to language in rational thought:

Intelligence, just because it undergoes a gradual process of socialization, is enabled through the bond established by language between thoughts and words to make an increasing use of concepts ... The mere fact, then, of telling one's thought, of telling it to others, or of keeping silence and telling it only to oneself must be of enormous importance to the fundamental structure and functioning of [rational] thought.... The fact of being or of not being communicable is not an attribute that can be added to thought from the outside, but is a constitutive feature of profound significance for the shape and structure which reasoning may assume (Piaget, 1923/1926, pp. 45-48).

Egocentric logic is, he argued, the result of having no desire to communicate one's thought; rational thought, on the other hand, develops through the desire to communicate it to others through social speech. However, egocentric speech was seen as a symptom of egocentric thought, having no purpose in forming intelligence—its attrition with development stemming from the socialisation of the child.

1.2.2 Vygotsky

The idea that egocentric speech has no function was first refuted by Vygotsky (1930-1935/1978, 1934/1987). Vygotsky's (1934/1987) own observations showed that, when an impediment to a young child's task is introduced, their production of egocentric speech increases, suggesting such speech is functionally related to task behaviour. He also claimed that, although egocentric speech might initially simply describe a child's activity as it happens, it eventually reliably occurs before the action it describes is performed, suggesting that it gradually takes on a planning and

directing function (Vygotsky, 1930-1935/1978; though this transition from “accompanying” to “preceding” has received only limited support in subsequent research, see Berk, 1992, and Duncan & Pratt, 1997).

Vygotsky’s (1934/1987) second main point was that egocentric speech does not just disappear over time as it is replaced by social speech, instead contending that it is internalised to form *inner speech*, or silent verbal thought. When Vygotsky and his coworkers introduced an impediment into older children’s activity, they tended to pause in silent contemplation, and when they were asked what they had thought about, their answers revealed similarities with the egocentric speech of younger children placed in the same situation. Studies in which adults were asked to think aloud also underlined the similarity between egocentric speech and inner speech in terms of their apparent function. Vygotsky also described their structural similarity, both forms of speech being comprehensible only to the speaker, abbreviated, and predicated.

Having argued that egocentric speech has a psychological function and that its fate comprises the formation of inner speech, Vygotsky (1934/1987) went on to consider its developmental origins. Unlike Piaget, he considered speech to have been social from its very beginning, and he proposed that the emergence of egocentric speech represents the differentiation of speech functions, with social (*interpsychological*) functions remaining and *intrapsychological* functions emerging.

In sum, then, for Vygotsky, “The actual movement in the development of the child’s thinking occurs not from the individual to some state of socialization but from the social to the individual ... it appears that egocentric speech is a transitional phase in the developmental process through which speech moves from the external to the inner plane” (1934/1987, pp. 76-77). The emergence of egocentric speech was

viewed as simply an example of the “child’s tendency to apply what were previously social forms of behaviour to himself” (p. 74): The child starts to talk to himself just as she already talks to others.

1.3 Evidence

Vygotsky thus states that the origin of egocentric speech is in social interaction and that its fate is in the formation of inner speech. The next section will show that these two claims have been largely supported in subsequent research. The other major implication of Vygotsky’s theory, in contrast to Piaget’s, is that egocentric speech is useful for cognition. Methods for testing whether or not this is true are introduced below and are discussed in more detail in Chapter 2. Because the evidence overwhelmingly supports the idea that egocentric speech is “speech for self” rather than failed social communication, it is hereafter referred to by its modern name, *private speech* (Flavell, Beach, & Chinsky, 1966).

1.3.1 Developmental origin of private speech

Vygotskian theory implies that, by participating in linguistically-mediated joint activity, a child creates (with their interactional partner) a dialogue that can be internalised to form self-regulatory private speech (Fernyhough, 1996, 2010). As Fernyhough (2010) explains, the implication is that words which were previously used by the child to regulate the thought and behaviour of others, or which others have used to regulate the child’s thought and behaviour, become employed in regulating the thought and behaviour of the child.

This shift from linguistically-mediated other-regulation to linguistically-mediated self-regulation has been demonstrated on a microdevelopmental basis,

during collaborative problem-solving sessions between adults and children. Winsler, Diaz, and Montero (1997) present a microdevelopmental analysis of preschoolers' performance on a selective attention task during a session in which an experimenter would verbally scaffold their activity when needed. After successful scaffolding, the children consistently used private speech, and more so than if no scaffolding had been given. Furthermore, after scaffolding, children were more likely to succeed if they used private speech than if they were silent. This relation between private speech and performance did not exist for trials following a lack of scaffolding. Therefore children's private speech (or linguistically-mediated self-regulation) seemed to mediate the link between linguistically-mediated other-regulation and their increasing competence on this executive task.

Winsler et al.'s (1997) is one of several studies linking adult behaviour in joint activity to children's subsequent private speech production. Children's private speech production during a task can be advanced by initially scaffolding their activity quite heavily and then, crucially, withdrawing control as they become more competent (Diaz, Winsler, Atencio, & Harbers, 1992; Winsler, Diaz, McCarthy, Atencio, & Adams Chabay, 1999). Thus, withdrawing control seems to enable a shift from other-regulation to self-regulation to take place, by allowing private speech to occur.

If there is an effect of adult-child interaction on self-directed speech, we would expect the development of self-regulatory private speech to differ in cultures that differ in terms of the usual mode of parent-child interaction. There have been two tests of this. In the first, Berk and Garvin (1984) studied 5- to 10-year-old children attending a mission school in the Appalachian Mountains of eastern Kentucky in the US. Central Appalachia is a region which is culturally quite distinct

from the rest of eastern North America. Berk and Garvin rightly portray it as economically deprived and socioculturally adult-centred. Importantly, there is markedly greater talkativeness between women and girls than between men and boys. The authors hypothesised that this would be reflected in sex differences in private speech development, favouring girls. The participants' private speech was observed in a variety of contexts during the school day. In terms of the frequency of private speech production, there was a sex difference for the "least mature" categories of private speech (e.g., task-irrelevant word play), with boys producing more than girls. For the "more mature" categories of private speech, there was a sex difference in the opposite direction. The private speech of the girls therefore appeared to be more advanced than that of the boys. Berk and Garvin's findings contrast with studies of private speech in other Western cultures, which have not found consistent sex differences. However, because there was no comparison group, it was not possible to see if this pattern was significantly different to that found in any other culture. It is possible that in Berk and Garvin's study there was something about the contexts in which private speech was recorded that biased the results in favour of girls.

A more recent study included a comparison group of British children (Al-Namlah, Fernyhough, & Meins, 2006). The culture of interest was that of Saudi Arabia, where there are cultural sex differences somewhat similar to those found in the Appalachian culture as described by Berk and Garvin (1984). However, instead of framing the sex difference in terms of the general talkativeness of males and females, Al-Namlah et al. are able to provide more detailed evidence pertaining to the types of parent-child interactions experienced by boys and girls in Arab cultures. They review evidence indicating that, in Arab countries, boys are more likely to be

parented in an authoritarian style, and girls in an authoritative style, suggesting that boys experience more controlling behaviour by parents, whereas girls experience more reciprocal interactions with parents. Saudi girls' interactions with parents are therefore more similar to the British child-centred mode of interaction, leading to a prediction that the private speech of girls would show more similarity across cultures than would the private speech of boys. Specifically, it was predicted that the dominance of authoritarian parenting of Saudi boys would not be conducive to the development of private speech, and therefore that Saudi boys would produce less private speech than their British counterparts. The results bore out these predictions. The effects of gender and nationality interacted in an ANOVA predicting private speech production, as hypothesised. This was entirely explained by variation in social speech production, and the authors conclude that the effect of culture was not specific to private speech. However, considering it was predicted that Saudi boys would produce less private speech than their British counterparts because their interactions with parents involved less social speech, the fact that the relation applied to both private speech and social speech could be viewed as entirely consistent with the hypotheses.

To summarise, private speech development appears to be influenced by adult-child interactions, as evidenced by experiments observing the effects of adult-child interactions on a microdevelopmental timescale, and by cross-cultural comparisons of children's private speech production.

1.3.2 The changing nature of private speech

Testament to its social origins is the observation that early private speech shares properties with social speech—that it is *parasocial*. Kohlberg, Yaeger, and

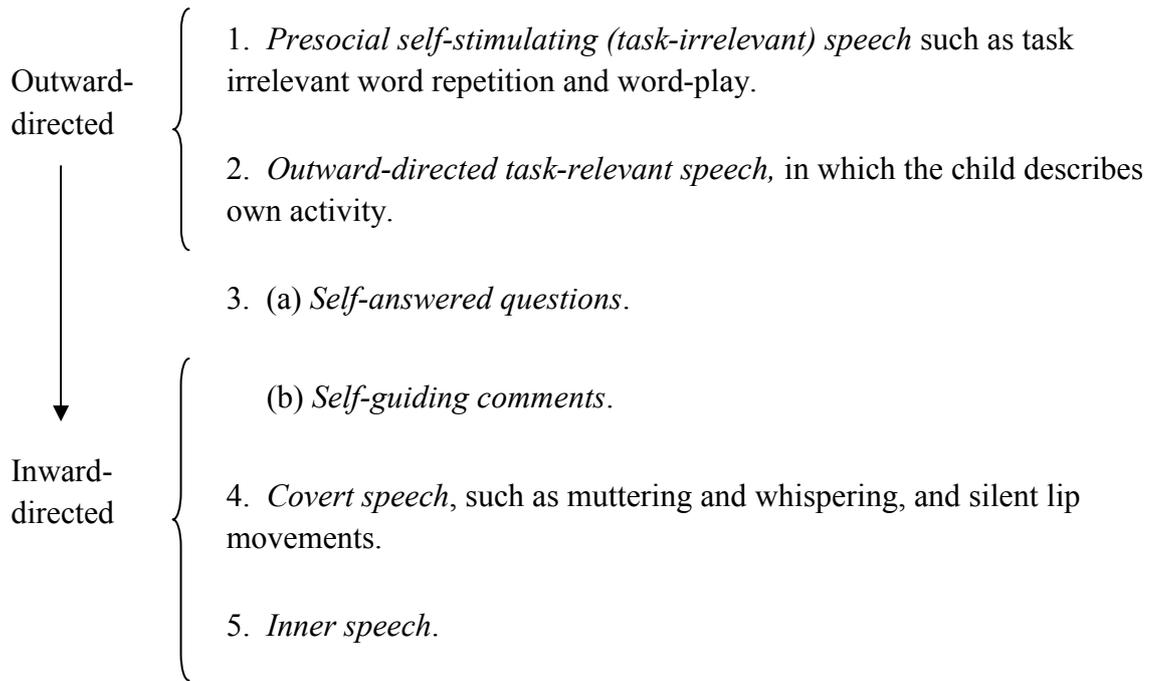
Hjertholm (1968) draw on the work of Mead as well as the work of Vygotsky to propose that children's private speech is initially like social speech in being *outward-directed*. They suggest that the young child's private speech takes the form of one half of a conversation, "with her own response in the role of the other being implicit and unvocalized" (p. 706). In the earliest stage it is not self-guiding but, rather, takes the form of task-irrelevant speech and then a mere *description* of the child's own activity, as if for an external auditor. Goudena (1987) later picked up the theme of private speech being outward-directed in early childhood, suggesting that it has a social function when uttered in the company of an adult or more skilled other—that function being to indirectly elicit their involvement in the child's activity.

These ideas produce at least two hypotheses concerning private speech in early childhood. One is that, while problem-solving, young children should produce more private speech in the presence of an experimenter who was previously helpful than in the presence of an experimenter who was previously unhelpful (Goudena, 1987). Goudena found this to be the case, but it is not known whether this pattern would be found for older children, so it is not possible to tell if private speech becomes less parasocial over time in this respect.

A second Vygotskian hypothesis is that private speech production should be positively correlated with social ability in early childhood (contra Piaget, who would predict more socialised children to produce less private speech). Indeed, Kohlberg et al. (1968) found positive associations between private speech production and teacher ratings of popularity on one hand, and the frequency of social speech production on the other, in young children. However, as Berk and Garvin (1984) point out, the study failed to find associations between private speech production and an observational measure of the maturity of social interactions. In addition, the relation

between private speech and social speech production might be entirely explained by individual differences in general verbosity or personality variables. Berk and Garvin instead hypothesised that earlier forms of private speech should be related to social speech production but that more mature forms should not. This was found to be the case, and it emerged that total private speech production did relate to social speech production in 5-year-olds but not in older children, suggesting private speech becomes less parasocial with age. In the same vein, Kohlberg et al. found that the proportion of private speech that is outward-directed is greater in 5- and 6-year-olds than in 8- and 9-year-olds. In sum, early private speech appears to be parasocial, and there is some evidence that its parasociality decreases with age.

According to Kohlberg et al. (1968), the next form of private speech in the developmental hierarchy, after outward-directed private speech, is an intermediate form in which the child takes on both sides of a dialogue, producing *self-answered questions*, for example. Finally, only the *inward-directed* half of the dialogue is vocalised, and private speech becomes *self-guiding* rather than merely descriptive. Eventually, even self-guiding comments cease to be uttered as private speech “goes underground” to form *inner speech*. The proposed developmental hierarchy can be summarised thus:



In a cross-sectional study of children making “sticker designs,” Kohlberg et al. (1968) found some support for this hierarchy. Level 1 speech was rare in all age groups, but was more frequent amongst 5-year-olds than 6- to 9-year-olds. Amongst 5 year-olds, the dominant speech category was describing one’s own activity (Level 2); amongst 6-year-olds, it was self-guidance (Level 3b); and amongst 8 and 9-year-olds, it was muttering (Level 4). The findings therefore suggested that children’s private speech becomes more inward-directed with age. In the final experiment of the paper, Kohlberg et al. provided further support for the hierarchy by showing that the categories formed a *simplex* pattern of correlations, whereby categories that were closer in the hierarchy were more closely correlated than those that were further apart.

Kohlberg et al.’s (1968) developmental hierarchy was later criticised on a number of grounds. Berk and Garvin (1984) contended that *describing one’s own activity* and *self-guidance* could not be reliably distinguished from each other in

practice and therefore should be merged, and that *self-answered questions* were only rarely observed. In addition, they called attention to the fact that the categories were not jointly exhaustive. Berk (1986) simplified the five-level hierarchy, and made it inclusive of all private speech, creating the following three-level coding scheme:

1. Task-irrelevant self-stimulating speech (corresponding to Kohlberg et al.'s Level 1)
2. Task-relevant externalised speech (corresponding to Kohlberg et al.'s Levels 2 and 3)
3. Less audible task-relevant speech (corresponding to Kohlberg et al.'s Level 4)

Berk's (1986) study of elementary schoolchildren completing mathematics work provided support for this three-level hierarchy: Grade 3 children produced significantly less private speech of Levels 1 and 2 than did Grade 1 children, and significantly more speech of Level 3. Subsequent cross-sectional studies comparing children of different ages using Berk's coding scheme confirm the idea that private speech becomes more covert during childhood (Berk & Potts, 1991; Berk & Spuhl, 1995; Bivens & Berk, 1990; Winsler, De León, Wallace, Carlton, & Willson-Quayle, 2003; Winsler & Naglieri, 2003), as do longitudinal studies following children over a period of 6 months or more (Winsler, Diaz, Atencio, McCarthy, & Adams Chabay, 2000; Winsler et al., 2003). Berk and Spuhl (1995) also found that young children's private speech becomes more covert on a microdevelopmental timescale. Thus, from the mid-1980s onwards, there was less emphasis on the outward-inward dimension, and more emphasis on the increasing covertness of private speech. Indeed, Diaz (1992) concluded that "the only evidence in support of a maturity-immaturity

dimension of private speech is its progression from overt (immature) to covert (mature)” (p. 72).

Particularly convincing evidence for internalisation comes from studies looking at how patterns of children’s private speech production change with repeated sessions of completing the same task, the sessions being separated by just a few days. The frequency of private speech production decreases on this timescale (Berk & Spuhl, 1995; Duncan & Pratt, 1997). Presumably the participants in these studies did not become significantly more “socialised” (Piaget, 1923/1926) over this short time, but, rather, the attrition of private speech rates was related to the participants’ increasing competence at the tasks, and therefore reflected not the disappearance of private speech, but its internalisation to form silent inner speech.

1.3.3 Inner speech

The idea that much of one’s thinking involves silently conversing with oneself is intuitively appealing, and it has found some support in studies using various methods relying on introspection. For example, a recent questionnaire study (Brinthaup, Hein, & Kramer, 2009) found a high level of endorsement of items assessing the use of inner speech for “everyday thinking” and self-regulation among adults. Similarly, using an experience sampling and interview technique, Hurlburt and colleagues found verbal inner experience to be common in typical adults (see Hurlburt, 1990; Hurlburt, Happé, & Frith, 1994). Winsler and Naglieri (2003) had children and adolescents complete a “trail-making” executive task, and found that around 35% of the oldest participants reported using inner speech. The extent to which we can know our own minds is a matter of much debate, however (see for example Nisbett & Wilson, 1977, and Hurlburt & Heavey, 2001). When asked to tell

the experimenter how they had done the trail-making task, only 5% of Winsler and Naglieri's 16- and 17-year-olds reported talking to themselves aloud, despite the fact that around 15% had been observed using private speech.

The presence of inner speech, if it has a beneficial effect on cognitive performance, can also be detected using the *dual task paradigm*. This paradigm has its roots in the working memory literature (see Baddeley, 1986). The original logic was that suppressing a function with a secondary task will eliminate any other effect dependent on that function. For example, *articulatory suppression* is a secondary task which blocks rehearsal of verbal information. If articulatory suppression eliminates the word length effect, whereby long words are remembered less well than short words, this indicates that the word length effect arises from participants' rehearsal of to-be-remembered words (specifically, that words with a longer spoken duration are subject to greater decay because they take longer to rehearse; Baddeley, Lewis, & Vallar, 1984). Articulatory suppression is particularly pertinent to the present thesis because it refers to secondary tasks in which participants repeat a word or well-learned sequence of words, which suppresses task-relevant verbal processes. The first time it was used to find out whether or not a task was reliant on Vygotskian "inner speech" was in a paper by Baddeley, Chincotta, and Adlam (2001), who found that articulatory suppression slowed adults' task-switching performance. Several similar studies followed (see Chapter 2), demonstrating detrimental effects of articulatory suppression on several other tasks that are not inherently verbal. Although not all authors refer to Vygotsky, the conclusions of these studies support the neoVygotskian idea that many cognitive functions are verbally mediated. Dual task studies and research on the increasing covertness of private speech together suggest that private speech does not simply disappear but instead is internalised.

1.4 The present thesis

The present thesis is therefore about the extent to which cognition is *verbally mediated* in typically and atypically developing children. Debates regarding whether or not certain concepts are made possible by language, and whether or not lower level perception is influenced by the language we speak (see Carruthers, in press), are beyond the scope of this thesis. It is instead concerned with the online use of language for cognition. Because private speech and inner speech are postulated to lie on the same developmental continuum, and because articulatory suppression interferes with both, the term *self-directed speech* will be used to encompass both where necessary (Figure 1.1). In this section the research reported in the thesis is briefly described, along with its context in terms of current issues in research on self-directed speech.

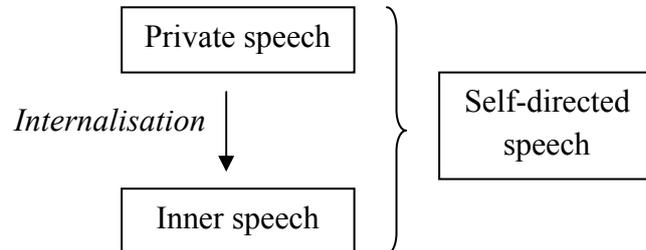


Figure 1.1. Conceptual relations between private speech, inner speech, and self-directed speech.

That speech takes on a planning function in early childhood is, as mentioned above, a central tenet of Vygotskian theory. Planning performance has been investigated in relation to self-directed speech in three previous studies but none of them employed the optimal methodology for discovering whether or not planning is dependent on self-directed speech (as this was not among their primary aims).

Therefore the research reported in Chapter 2 compares 7- to 11-year-olds' Tower of London performance under articulatory suppression with their performance while foot-tapping. Arguably its main contribution, though, is to combine the use of articulatory suppression with the observation of private speech. Relations between individual differences in private speech production and articulatory suppression interference were investigated in order to provide further evidence that articulatory suppression interference operates by suppressing self-directed speech rather than through general dual task demands. The "combined" methodology was then used in the research reported in Chapter 3, and its value for future research is considered further in the General Discussion (Chapter 6).

A theme of the present thesis is how the development of self-directed speech might be affected by developmental disorders. Given the prominent role of language in self-regulation, the first type of pathology to be studied in private speech research was ADHD, a disorder affecting self-regulation. A consistent finding in this area is that unmedicated children with ADHD produce more private speech and less-internalised private speech than their peers (see Winsler, 2009). The interpretation of this group difference is difficult, but it might represent a delay in self-directed speech development that contributes to the self-regulation problems that children with ADHD experience. Alternatively, the production of an abundance of overt private speech by children with ADHD might represent an adaptive attempt by these children to overcome their symptoms (Winsler, 2009). A third possibility is that it is hyperactivity that makes speech more overt in children with ADHD.

Although there are still unanswered questions relating to the development of self-directed speech in ADHD, a lot of potentially enlightening research has been done. In contrast, there has been only a very recent boom in research on self-directed

speech in autism. Autism is the subject of Chapter 3 of the present thesis, and in Section 3.1 the rationale of this research is described in some detail. The empirical work of Chapter 3 consists of a reanalysis of data from previously published work looking at the effect of articulatory suppression on task-switching in children with autism and typically developing controls. The reanalysis suggests that it is important to consider the language abilities of individuals with autism (more specifically the relation of their verbal ability to their nonverbal ability) when thinking about their self-directed speech.

Chapter 4 comprises an original study of self-directed speech in children with *specific language impairment* (SLI) using the methodology developed in Chapter 2. Children with this diagnosis show language impairment but relatively intact nonverbal IQ. In spite of this, they do exhibit impaired performance on several nonlinguistic tasks, and it has been suggested several times that this might be related to impaired self-directed speech. The research reported in Chapter 4 constitutes the first study of self-directed speech in SLI. Children with SLI and typically developing controls were compared in terms of the vulnerability of their Tower of London performance to articulatory suppression, and in terms of the internalisation level of their private speech during performance of the Tower of London and a digit span task. This allowed the measurement of the extent to which their cognition relied on self-directed speech, and the measurement of how advanced the groups' private speech was, in relation to each other. The results suggested that research on self-directed speech might prove to be helpful in terms of understanding some of the nonlinguistic deficits found in SLI.

In the course of the SLI study, it became apparent that it was not just the Tower of London and digit span tasks that elicited private speech: The Spatial IQ

tasks used for group matching did too. When the rates of private speech production during the Spatial IQ tasks was quantified, it was found that private speech was produced during about 20% of trials on average, and that there were large positive correlations in individual differences in private speech production among all four tasks. Cross-task correlations have rarely been reported, despite the fact that whether or not we can expect cross-task consistency is an important issue from the point of view of the *reliability* or otherwise of private speech production. Cross-task correlations also speak to the extent to which the development of verbal mediation can be considered to be *domain-general* (see Al-Namlah et al., 2006). Therefore the first 30 typically developing children who completed all four tasks were followed up 11 months later to see if the findings on cross-task consistency would be replicated, and in order to assess other psychometric properties of private speech production—longitudinal stability and cross-context consistency. This study is reported in Chapter 5.

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Self-Directed Speech and Planning

This chapter comprises the following manuscript: Lidstone, J. S. M., Meins, E., & Fernyhough, C. (2010) *The roles of private speech and inner speech in planning in middle childhood: Evidence from a dual task paradigm*. It is the first revision of a paper submitted to the *Journal of Experimental Child Psychology*.

2.1 Abstract

Children often talk themselves through their activities, producing private speech, which is internalised to form inner speech. The present study assessed the effect of articulatory suppression (which suppresses private and inner speech) on Tower of London performance in 7- to 10-year-olds. Experiment 1 ($N = 30$) showed no effect of articulatory suppression on performance with the standard Tower of London procedure; we interpret this in terms of a lack of planning in our sample. Experiment 2 ($N = 30$) used a modified procedure in which participants were forced to plan ahead. Performance in the articulatory suppression condition was lower than in the nonverbal control condition, consistent with a role for self-directed (private and inner) speech in planning. On problems of intermediate difficulty, participants producing more private speech in the nonverbal control condition showed greater susceptibility to interference from articulatory suppression than their peers, suggesting that articulatory suppression interfered with performance by blocking self-directed (private and inner) speech.

2.2 Introduction

Vygotsky (1934/1987) saw higher mental functions such as flexible goal-directed thought as being founded upon the experience of participating in dialogue around joint activity. The ability to regulate one's own thought and behaviour is seen as emerging from the experience of taking part in interactions in which adult and child use speech to direct each others' thought and behaviour. When children first use speech to direct their own thought and behaviour, they are said to be producing *private speech*. Private speech describes utterances spoken aloud that appear to serve a self-regulatory function rather than a communicative function: They are self-directed, and often take the form of self-guiding comments. Private speech is mainly found in preschoolers, but can appear in middle childhood and adulthood, when it is likely to take the form of more covert muttering and whispering (see Winsler, 2009). It is thought that this shift towards covertness reflects the gradual internalisation of private speech to form inner speech, or silent verbal thought (Vygotsky, 1934/1987). Private speech and inner speech together are hereafter referred to as self-directed speech (Figure 2.1).

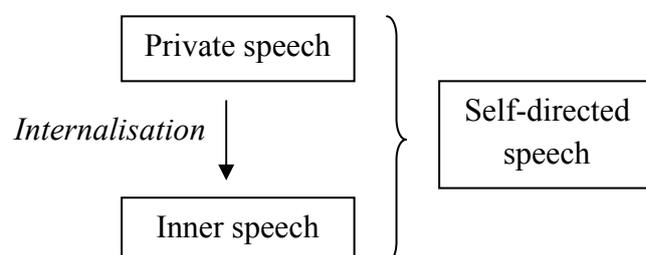


Figure 2.1. Conceptual relations between private speech, inner speech, and self-directed speech.

Self-directed speech has been implicated in the performance of problem-solving tasks, some spatial working memory tasks, and executive functions, in studies which will be described below. Some of this evidence comes from studies relating private speech production to task performance. A cognitive task is thought to be reliant on self-directed speech if private speech production predicts either concurrent or future performance in children. For example, Winsler, Diaz, and Montero (1997) had preschoolers perform a selective attention task, each trial of which required them to determine which of two perceptual dimensions (shape or colour) was shared by two pictures, and then to select, from a group of alternatives, an answer card representing the shared dimension. After receiving guidance from an experimenter, children were more likely to succeed if they used private speech than if they were silent. Similarly, Behrend, Rosengren, and Perlmutter (1989, 1992) found that preschoolers' private speech production during spatial problem-solving tasks correlated with both their concurrent and future performance of those tasks.

However, there are a number of problems with looking at private speech–performance relations to speak to whether or not tasks are reliant on self-directed speech. One is that private speech production shows a positive or curvilinear relation with task difficulty, and if this is not taken into account private speech–performance relations can be missed (see Fernyhough & Fradley, 2005; Frauenglass & Diaz, 1985). Even when they are found, the difficulty with a non-experimental design is that it leaves open the question of whether private speech is useful for or merely happens to accompany successful cognitive performance.

An approach that avoids these problems is to use the dual task paradigm to assess the effect of preventing self-directed speech. The experimental design allows researchers to investigate whether or not self-directed speech has a causal role in

cognitive performance. Researchers can prevent the use of self-directed speech by asking participants to engage in an *articulatory suppression* task concurrently with the primary task on which performance is being assessed. Articulatory suppression can take the form of repeating a word, repeating a well-learned sequence of words like the months of the year, or shadowing prose heard while completing the primary task. (Articulatory suppression is usually referred to as suppressing “inner speech,” but of course it interferes with private speech as well.) If performance of the primary task relies on self-directed speech, it should be significantly impaired by articulatory suppression. The performance of several cognitive tasks is vulnerable to articulatory suppression in children and adults, including tasks tapping spatial working memory (Ang & Lee, 2008), and task-switching (Whitehouse, Maybery, & Durkin, 2006) in children, and tasks tapping spatial reasoning (Kim, 2002), cognitive flexibility (Baldo et al., 2005) and task-switching performance (Baddeley, Chincotta, & Adlam, 2001) in adults.

In many of these studies, performance in the articulatory suppression condition was compared to performance in a control condition with no secondary task. However, as Emerson and Miyake (2003) point out, the effect of articulatory suppression in some cases might be wholly attributed to the general demands of performing two tasks simultaneously. To guard against this possibility, a nonverbal secondary task, such as foot-tapping, can be included in the control condition. If the articulatory suppression task is to say *a b c* once every metronome beat, the control task would be to tap one’s foot once every metronome beat. If the articulatory suppression task is verbal shadowing, an appropriate control condition could involve shadowing a rhythm by foot-tapping. Foot-tapping is thought to be a good control task because, like articulatory suppression, it incorporates a motor component, and it

involves an attentional component that is similar to that of articulatory suppression (Robbins et al., 1996). Its suitability was tested by Emerson and Miyake (2003), who found that, on a visual task assumed to be completely nonverbal (the Identical Pictures Test), articulatory suppression and foot-tapping affected adults' performance equally. Foot-tapping is now included in the control conditions of studies assessing the effect of articulatory suppression on task-switching. They show that articulatory suppression impairs performance to a greater extent than does foot-tapping (e.g., Emerson & Miyake, 2003; Liefoghe, Vandierendonck, Muylaert, Verbruggen, & Vanneste, 2005; Saeki, Saito, & Kawaguchi, 2006), suggesting that task-switching relies on self-directed speech. Other research has revealed effects of articulatory suppression on spatial reorientation (that is, the ability to integrate geometric and landmark cues in order to reorient oneself in space after disorientation; Hermer-Vasquez, Spelke, & Katsnelson, 1999) and face learning (Nakabayashi & Burton, 2008) compared to tapping control conditions.

One function that has received surprisingly little attention in research on self-directed speech is that of planning. Planning is surely one of the most common human mental activities, and is at the very core of goal-directed behaviour (Cohen, 1996). According to Vygotskian theory, self-directed speech has a special role in planning. Vygotsky's own studies suggested that one of the most significant developments of private speech in the preschool years is that it takes on a planning function. Upon discovering the planning function of speech, he argues, "[children's] psychological field changes radically. A view of the future is now an integral part of their approaches to their surroundings" (Vygotsky, 1930-1935/1978, p. 29). He argues that speech (or "verbal signs") is helpful in acting as a barrier between impulsive and actual behaviour. Thus, "the inclusion of signs ... creates the

conditions for the development of a single system that includes effective elements of the past, present, and future. This emerging psychological system in the child now encompasses two new functions: intentions and symbolic representations of purposeful action” (pp. 36-37).

On this view, self-directed speech should be particularly useful for the performance of tasks requiring planning in childhood. The gold standard planning tasks are the Tower of Hanoi, and its more commonly used adaptation, the Tower of London (Shallice, 1982). The Tower of London consists of three different-coloured disks, arranged on three pegs that can hold one, two, and three disks respectively (Figure 2.2). Participants attempt to transform one configuration into another by moving one disk at a time. Planning is required because participants must complete the task in the smallest number of moves possible.

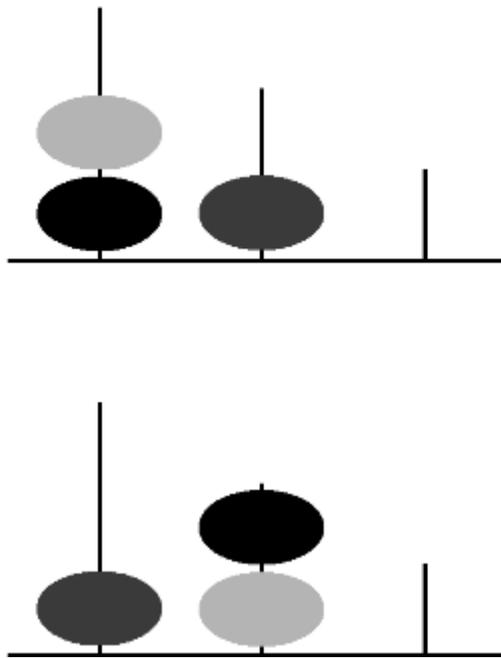


Figure 2.2. Example Tower of London problem. Top: start state. Bottom: goal state.

Actual colours were red, green, and blue.

To our knowledge, there are in the extant literature four studies with results that speak directly to whether or not self-directed speech is involved in Tower of London or Tower of Hanoi performance; they all relate to the Tower of London. The first to be considered here is a study of the private speech of 5- and 6-year-olds while completing the Tower of London (Fernyhough & Fradley, 2005). The authors found that children producing more private speech completed the task more quickly and accurately than children who produced less. This was partially replicated by Al-Namlah, Fernyhough, and Meins (2006), who found a negative association between private speech production and the time taken to complete Tower of London problems in their sample of 4- to 8-year-olds. These findings are consistent with the idea that successful planning requires self-directed speech in early childhood.

Wallace, Silvers, Martin, and Kenworthy (2009) reported the effect of articulatory suppression on Tower of London performance in a group of typically developing adolescents (12- to 19-year-olds)—the control group in a study of “inner speech” in autism. The participants completed Tower of London problems, alternately with and without articulatory suppression. Under articulatory suppression, the typically developing participants took significantly more moves to complete the problems than they did without articulatory suppression. The authors interpreted the results to mean that inner speech supported performance in their sample of typically developing adolescents. Because there was no control secondary task, however, the results are open to the alternative interpretation mentioned above: that the effect of articulatory suppression could be wholly attributed to general dual task effects.

The fourth study (Phillips, Wynn, Gilhooly, Della Sala, & Logie, 1999) also did not include a secondary task in the control condition, but this was less problematic for our purposes given the pattern of results. The participants, young

adults aged 18 to 25 years, completed Ward and Allport's (1997) five-disk Tower of London with and without articulatory suppression. Articulatory suppression was not detrimental to performance accuracy (defined in terms of the number of excess moves) for problems of any level of difficulty. The effect of articulatory suppression was only to speed up performance, although its effect in reducing planning times (time to first move) mainly occurred for the most difficult problems, which were too complex to be planned in full even with no secondary task (Phillips, Wynn, McPherson, & Gilhooly, 2001).

Thus there are three studies (Al-Namlah et al., 2006; Fernyhough and Fradley, 2005; Wallace et al., 2009) suggesting a role for self-directed speech in planning, but none used dual task methodology with a dual task control condition. The other study (Phillips et al., 1999) is perhaps the most conclusive of these four investigations in terms of our question of whether self-directed speech is important for planning, suggesting it is not. The lack of articulatory suppression interference on planning accuracy in adults does not preclude the possibility of finding an effect earlier in development, however. We predicted that planning would be largely dependent on self-directed speech in middle childhood. To test this hypothesis was the principal aim of the present study. Specifically, we predicted that Tower of London performance would be impaired under articulatory suppression relative to a control condition with a foot-tapping task.

The second hypothesis was that the detrimental effect of articulatory suppression on performance would be larger for children whose performance relied on self-directed speech to a greater extent, as evidenced by more frequent private speech production in the tapping condition. In this way we hoped to provide further evidence that articulatory suppression has its detrimental effect on primary task

performance by interfering with self-directed speech, rather than through general dual task demands. We expected to find a relation between private speech production and interference by articulatory suppression only for problems for which private speech was useful. Like Fernyhough and Fradley (2005), who looked at private speech–performance relations, we expected the utility of private speech to be moderated by task difficulty. For the easiest problems, we expected speech to be mainly fully internalised, meaning that private speech production would be a good indicator of the extent to which performance was reliant on self-directed speech for intermediate and difficult problems only. For the most difficult problems, beyond the children’s ability range, private speech was predicted to be ineffective for improving performance in the control condition. We therefore predicted a positive relation between private speech production and interference by articulatory suppression only for problems of intermediate difficulty. Inner speech, on the other hand, was predicted to be useful for the easiest problems. As articulatory suppression interferes with both private speech and inner speech, we expected articulatory suppression to be detrimental to performance on the easiest problems as well as those of intermediate difficulty.

2.3 Experiment 1

In Experiment 1, we sought to test the two hypotheses described above—that planning would be disrupted by articulatory suppression in middle childhood, and that the amount of private speech produced in the foot-tapping condition would correlate positively with articulatory suppression interference for problems of intermediate difficulty.

2.3.1 Method

2.3.1.1 Participants

The participants were 30 typically developing children (13 boys), recruited from and tested in mainstream state schools in the North-East of England. The mean age of the children was 9 years; 1 month (*SD* 0;9, range 7;11 – 10;5). No participant had a learning or neurological disorder according to teacher report. All had active written parental consent to participate, and were free to withdraw at any time.

2.3.1.2 Materials

The Tower of London consisted of two wooden frames, each with three coloured disks (Figure 2.2). A camcorder recorded the testing sessions. A program on a laptop computer, connected to a foot pedal, was used for the tapping task: It produced sounds to allow participants to monitor their foot-tapping performance (see below). The pedal was mounted on a wooden platform, which incorporated an adjustable foot rest.

There were two sets of 13 Tower of London problems—10 experimental problems plus 3 practice problems—one set for each condition. The problem sets were identical except that the colours of the disks were swapped around; that is, the sets were isoforms of each other. The practice trials were 1-, 2-, and 3-move problems, none of which were duplicated in the experimental problem set. The experimental problem set consisted of two 2-move problems, three 3-move problems, three 4-move problems, and two 5-move problems. No problem appeared in the same problem set twice. Although the minimum number of moves is not the only aspect of Tower of London problems that influences task difficulty (Kaller,

Unterrainer, Rahm, & Halsband, 2004), it is hereafter used as a rough guide to the difficulty level of the problems.

2.3.1.3 Procedure

The participants completed the two dual task conditions in a single session. The order of conditions was counterbalanced so that the two groups—those receiving the tapping condition first and those receiving the articulatory suppression condition first—did not differ in gender composition or chronological age.

The participants were told that their job was to make the two puzzles look the same, by moving one disk at a time, and that they would “need to plan ahead” to do so in the minimum number of moves. The problems were presented in order of increasing difficulty, and the participants were told the number of moves they should use to solve each problem. Participants received a sticker for each problem they solved in the minimum number of moves and another for each problem that was completed with no secondary task errors.

The secondary tasks, repeating the word *Monday* (articulatory suppression) and foot-tapping (control), were demonstrated by the experimenter, who performed them at a rate of one response per second. Participants then practised the secondary tasks with the Tower of London practice trials.

In the tapping condition, each tap on the pedal produced a beep. If there was an error, defined as a gap between taps of 2.0 seconds—equal to missing one tap—there was a warning sound, which ceased when tapping was recommenced.

In the articulatory suppression condition, the experimenter said *Monday* in time with the participant. If a participant made an error, defined as a missed *Monday*, the experimenter reminded her to recommence by uttering her name.

2.3.1.4 Scoring and analysis

Two commonly-used measures of Tower of London performance are the number of excess moves (i.e., the difference between the number of moves taken to solve a problem and the minimum number of moves), and whether or not a problem was solved in the minimum number of moves (Berg & Byrd, 2002). The latter was more compatible with the instructions given to participants (which were designed to focus their attention on the need for careful planning) and this measure had the advantage of rendering the results of Experiments 1 and 2 comparable. The primary outcome measure for each trial was therefore whether or not it had been solved in the minimum number of moves. A trial was considered to have ended after the first incorrect move, as incorrect sequences of moves often ended in an impasse and participants were stopped by the experimenter. The secondary performance measure, time taken to complete the problems, was therefore measured only for correctly-solved problems. The third measure of performance on each trial was whether or not one or more secondary task errors had been made before the end of the trial.

The participants' speech in the tapping condition was coded from the video recordings. Private speech was defined as any speech that did not meet the criteria to be regarded as social speech (Winsler, Fernyhough, McClaren, & Way, 2005). Social speech was defined as any full volume speech intended for communication with the experimenter. Communicative intent was identified where the participant involved the experimenter (through physical contact, gaze direction, etc.), during or within two seconds of an utterance (Winsler et al., 2005). The frequency of social speech was negligible so it is not reported.

Private speech is traditionally coded according to Berk (1986) as *Level 1* (task-irrelevant private speech), *Level 2* (task-relevant externalised private speech), or *Level 3* (presumably task-relevant external manifestations of inner speech, including inaudible muttering and whispering, and silent, verbal lip movements). However, the frequency of task-irrelevant private speech was negligible, and the internalisation level of private speech was not relevant to our hypothesis. Therefore each trial was coded as containing or not containing task-relevant private speech (Levels 2 and 3 together). A trial-based metric was chosen as rate-based metrics (such as utterances per minute) risk confounding general verbosity with the degree of dependence on private speech (Winsler et al., 1997), especially where it is not possible to control for verbosity by partialling out social speech production (see Winsler et al., 2005). A second researcher independently coded 20% (six) of the recordings. Inter-rater agreement for the presence of private speech was $\kappa = .87$.

The frequency of private speech was a function of the percentage of trials containing private speech. In order that the results would be directly comparable to those of Experiment 2, which had an equal number of problems of each level of difficulty, we applied a weighting to the problems of Experiment 1. Private speech rates were weighted so that each difficulty level was represented equally. For example, without weighting, a child producing private speech during the performance of neither 2-move problem, all three 3-move problems, all three 4-move problems and neither 5-move problem would score 60%. With weighting, the rate would be the mean of 0%, 100%, 100%, and 0%, which is 50%.

The principal measure of task performance in each condition was the percentage of problems solved in the minimum number of moves, with the weighting system applied. Other measures of task performance were the time taken to complete

correctly-performed problems, and the percentage of problems containing a secondary task error. The same weighting system applied to all performance variables. For response times, the mean time was found for correctly-performed 2-, 3-, 4-, and 5-move problems separately, and then the grand mean was taken. The weighting system did not change the results of any statistical test: It simply made the accuracy of Tower of London performance more comparable across experiments.

Parametric statistics were used throughout. Although one of the variables (the proportion of problems containing a secondary task error) was positively skewed, parametric statistics were robust because the distribution was the same in each condition, the variances were similar, and there were more than 20 degrees of freedom (Tabachnick & Fidell, 2007). Because there were only two or three trials at each level of difficulty, all analyses were performed initially without difficulty level as an independent variable, with 2×2 (Condition [articulatory suppression, tapping] \times Condition Order [articulatory suppression first, tapping first]) repeated measures ANOVAs. Difficulty level was included in a second analysis of the percentage of Tower of London trials solved correctly, in a $2 \times 2 \times 4$ (Condition [articulatory suppression, tapping] \times Condition Order [articulatory suppression first, tapping first] \times Difficulty Level [2-, 3-, 4-, 5-moves] ANOVA, as the effect of articulatory suppression was expected to vary with this. As the two ANOVA models produce exactly the same pattern of results with respect to the effect of condition and condition order, only the $2 \times 2 \times 4$ ANOVA is presented.

2.3.2 Results and discussion

In the control condition, the mean proportion of trials with private speech in the control condition was 7% (*SD* 11, range 0 to 50). The mean (*SD*) percentage of

trials with private speech for 2-, 3-, 4-, and 5-move problems was 5 (15), 9 (15), 6 (13), and 10 (24), respectively.

Performance in terms of the percentage of problems solved correctly is shown in Figure 2.3. A $2 \times 2 \times 4$ (Condition [articulatory suppression, tapping] \times Condition Order [articulatory suppression first, tapping first] \times Difficulty Level [2-, 3-, 4-, 5-moves]) repeated measures ANOVA was used to predict the percentage of problems solved correctly. There was a main effect of difficulty level, $F(3, 84) = 75.60, p < .001$. Within-subjects contrasts revealed a linear trend, $F(1, 29) = 184.96, p < .001$, with performance decreasing with increasing difficulty level. There was neither a main effect of condition, $F < 1$, nor a Condition \times Difficulty Level interaction, $F < 1$. No other effects approached significance (all $ps > .25$).

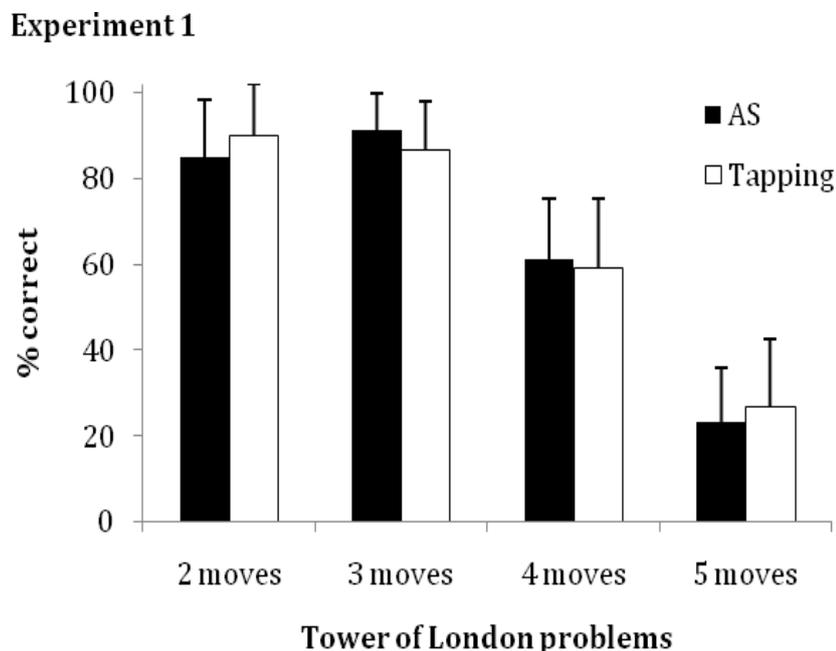


Figure 2.3. Experiment 1: Percentage of Tower of London trials solved correctly, in the articulatory suppression (AS) and tapping conditions. Error bars indicate $0.5 \times SD$.

In terms of the time taken to complete correctly-performed trials, there were no effects of condition, $F < 1$, or condition order, $F < 1$, and there was no Condition \times Condition Order interaction, $F(1, 28) = 1.50, p = .23$. Thus, there was no difference in the time taken to complete correctly-performed trials in the articulatory suppression condition, $M = 8.7$ s, $SD = 2.3$, compared with the control condition, $M = 8.3$ s, $SD = 3.4$.

In terms of the percentage of trials with a secondary task error, there was no main effect of condition order, $F(1, 28) = 1.06, p = .31$. There was a marginally significant main effect of condition, $F(1, 28) = 4.32, p = .05$, with more errors in the articulatory suppression condition, $M = 11.9\%$, $SD = 16.1$, than in the control condition, $M = 5.6\%$, $SD = 9.7$. However, this was modified by a Condition \times Condition Order interaction, $F(1, 28) = 6.87, p = .01$. Follow-up t -tests showed that, amongst those receiving articulatory suppression first, the secondary task error rate was higher in the articulatory suppression condition, $M = 17.8\%$, $SD = 19.6$, than in the tapping condition, $M = 3.3\%$, $SD = 6.9, t(14) = 2.79, p = .01$. Among participants receiving the tapping condition first, there was no difference in secondary task error rate between the articulatory suppression condition, $M = 6.1\%$, $SD = 9.0$, and the tapping condition, $M = 7.8\%$, $SD = 11.8, t(14) = 0.50, p = .62$.

In sum, there were more secondary task errors in the articulatory suppression condition than in the tapping condition, but this was limited to participants receiving the articulatory suppression condition first. Articulatory suppression had no effect on Tower of London performance, suggesting the latter was not dependent on self-directed speech. Therefore the second hypothesis was not tested.

In response to these results, the video recordings were re-examined. We recorded the time taken to initiate the first move for each trial—the planning time (see Berg & Byrd, 2002)—in the control condition. We chose the control condition rather than the articulatory suppression condition because the former is the condition in which planning is theoretically uninhibited. One participant's video recording was lost after a technical problem with the camcorder, so the results on planning times relate to 29 participants.

This analysis revealed planning times to be very short, $M = 3.1$ s, $SD = 1.1$. In addition, planning times did not increase with the difficulty level of the problems: Means in seconds (with standard deviations in parentheses) for 2- through 5-move problems were 2.7 (1.5), 3.5 (1.6), 2.9 (1.5), and 3.4 (2.5) respectively. The lack of relation between planning times and difficulty level was confirmed by a repeated measures ANOVA: There was no effect of difficulty level on planning times, $F(3, 84) = 1.90$, $p = .14$, and the within-subjects contrasts indicated no significant linear trend, $F(1, 28) = 0.75$, $p = .39$.

These planning times are markedly shorter than those in Phillips et al. (1999), which averaged around 15 seconds in the control condition (planning times are not reported in Fernyhough & Fradley, 2005, Al-Namlah et al., 2006, or Wallace et al., 2009). In addition, unlike in Phillips et al., planning time did not increase with trial difficulty. From this analysis, we concluded that performance in the present study was not dependent on self-directed speech perhaps because the procedure was not effective in eliciting planning. We therefore conducted a second experiment using another Tower of London procedure in which participants were forced to plan ahead. Instead of asking participants to move the disks to make the configurations match, we asked them to mentally plan the moves, to tell the experimenter the minimum

number of moves it would take to make the configurations match, and then to demonstrate the moves they had planned. The original *How many moves* procedure, in which participants did not have to additionally demonstrate the moves, was created by Owen et al. (1995) for use with adults, and has been used in several subsequent neuroimaging studies (e.g., Baker et al., 1996; Boghi et al., 2006). The predictions were as for Experiment 1.

2.4 Experiment 2

2.4.1 Method

2.4.1.1 Participants

The participants were 30 typically developing children (16 boys), recruited in the same way as the participants in Experiment 1. No child participated in both experiments. The mean age was 9 years; 4 months (*SD* 0;9, range 7;10 – 10;8).

2.4.1.2 Materials

All materials were as above, except that in Experiment 2 there were 8 instead of 10 experimental problems per condition. The number of problems was changed so that there could be an equal number of problems of each difficulty level, i.e., two 2-move, two 3-move, two 4-move, and two 5-move problems. This was to ensure that guessing 3 moves or 4 moves would not be reliably more effective than guessing 2 moves or 5 moves.

2.4.1.3 Procedure

In each condition, the problems were administered in a different pseudo-randomised order. Pilot work indicated that the children would need more than the three practice problems provided in Experiment 1, so they completed one practice set of eight problems, before completing the dual task conditions in a second session about a week later. The order of dual task conditions was counterbalanced as before.

As the Tower of London was introduced, the participants were asked “to imagine moving the disks around, one at a time, and tell [the experimenter] how many moves it would take to make [the start state] look like [the end state].” For the experimental problems, participants were just asked “How many moves?” for each trial. Unlike in previous studies using this version of the Tower of London (Baker et al., 1996; Boghi et al., 2006; Owen et al., 1995), the participants were asked to demonstrate the moves after telling the experimenter the number of moves they had planned.

The details of the secondary tasks were as above. They were performed only during the planning phase, the period between the start of the trial and the verbal response. Similarly, only the planning phase was coded for private speech.

2.4.1.4 Scoring and analysis

A Tower of London problem was scored as correct if the participant both named and correctly demonstrated the minimum number of moves required to make the start and end states match. The response time—the time from presentation of a problem to the verbal numerical response—was also recorded. As in Experiment 1, trials were coded dichotomously on the basis of whether or not a secondary task error had been made.

Private speech was coded as in Experiment 1. Inter-rater reliability was $\kappa = .90$. Video recordings were unavailable for one participant because of a technical problem with the camcorder, so the response time and private speech data relate to 29 participants.

No weighting system was used in Experiment 2 as there was an equal number of problems at each level of difficulty. As in Experiment 1, the principal measure of task performance was the percentage of problems solved in the minimum number of moves. Other measures of performance were response times, and the percentage of problems containing a secondary task error. Analyses were performed as in Experiment 1.

2.4.2 Results and discussion

As for Experiment 1, a $2 \times 2 \times 4$ (Condition [articulatory suppression, tapping] \times Condition Order [articulatory suppression first, tapping first] \times Difficulty Level [2-, 3-, 4-, 5-moves]) repeated measures ANOVA was used to predict the percentage of problems solved correctly. There was a main effect of condition, $F(1, 29) = 10.55, p = .003$; performance was impaired in the articulatory suppression condition compared to the control condition (Figure 2.4). There was a main effect of difficulty level, $F(3, 87) = 86.80, p < .001$, but no Condition \times Difficulty Level interaction, $F < 1$, with articulatory suppression affecting performance at all difficulty levels equally. No other effects approached significance ($ps > .15$).

Response times and secondary task error rates were analysed using 2×2 (Condition [articulatory suppression, tapping] \times Condition Order [articulatory suppression first, tapping first]) repeated measures ANOVAs. In terms of response times, there was no effect of condition, $F(1, 27) = 1.31, p = .26$. Thus, the response

times in the articulatory suppression condition, $M = 13.4$ s, $SD = 4.5$, did not differ from those in the tapping condition, $M = 14.3$ s, $SD = 3.8$. There was no main effect of condition order, $F < 1$, but the Condition \times Condition Order interaction approached significance, $F(1, 27) = 3.52$, $p = .07$. Follow-up t -tests showed that, among participants receiving the articulatory suppression condition first, there was no difference in response times between the articulatory suppression condition, $M = 14.1$ s, $SD = 5.4$, and the tapping condition, $M = 13.4$ s, $SD = 3.1$, whereas, among those receiving the tapping condition first, response times were shorter in the articulatory suppression condition, $M = 12.6$ s, $SD = 3.5$, than in the tapping condition, $M = 15.3$ s, $SD = 4.3$, $t(13) = 2.63$, $p = .02$. The participants who received the tapping condition first thus exhibited an improvement in their response times, unlike those receiving the articulatory suppression condition first.

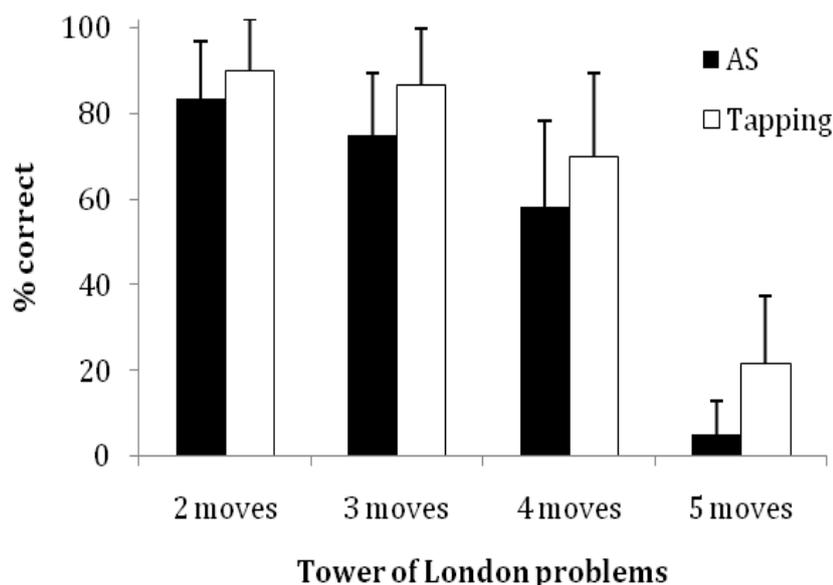


Figure 2.4. Experiment 2: Percentage of Tower of London trials solved correctly, in the articulatory suppression (AS) and tapping conditions. Error bars indicate $0.5 \times SD$.

In terms of the percentage of trials with a secondary task error, there was a main effect of condition, $F(1, 28) = 7.76, p = .01$, with more articulatory suppression errors, $M = 19.6\%$, $SD = 17.3$, than tapping errors, $M = 8.8\%$, $SD = 12.8$, as in Experiment 1. There was a marginally significant main effect of condition order, $F(1, 28) = 3.92, p = .06$, which was not modified by a Condition \times Condition Order interaction, $F < 1$. The proportion of trials with secondary task errors was lower among those receiving articulatory suppression first than among those receiving tapping first in both the articulatory suppression condition, $M = 14.1\%$, $SD = 16.3$, vs. $M = 25.0\%$, $SD = 17.0$, and the tapping condition, $M = 6.6\%$, $SD = 12.4$ vs. $M = 10.9\%$, $SD = 13.3$. Perhaps receiving the articulatory suppression condition first biased the participants toward allocating more attentional resources to the secondary task. Considering the deleterious effect of articulatory suppression on primary task performance, and the fact that participants were rewarded equally for perfect articulatory suppression performance and perfect Tower of London performance (with one sticker for each), this would be the optimum strategy in the articulatory suppression condition, and it was presumably carried over to the tapping condition by participants receiving this second. Overall, though, secondary task performance was poorer in the articulatory suppression condition than the tapping condition.

In sum, Tower of London performance appeared to be dependent on self-directed speech in Experiment 2. Tower of London performance and secondary task performance were lower in the articulatory suppression condition than in the control condition. The fact that the effect of articulatory suppression on primary task performance did not vary by difficulty level is discussed below.

To find out whether the effect of condition on Tower of London performance in Experiment 2 was significantly different from that in Experiment 1, we combined the results into a single $2 \times 2 \times 4$ (Experiment [Experiment 1, Experiment 2] \times Condition [articulatory suppression, tapping] \times Difficulty Level [2-, 3-, 4-, 5-moves]) ANOVA predicting the percentage of problems solved correctly. There was a main effect of condition, $F(1, 58) = 6.49, p = .01$, which was modified by a Condition \times Experiment interaction, $F(1, 58) = 5.64, p = .02$. Results shown above indicate this was due to an effect of dual task condition in Experiment 2 but not in Experiment 1. There was a main effect of difficulty level, $F(3, 174) = 159.76, p < .001$; no other effects approached significance (defined as $p < .10$).

The absence of a main effect of Experiment in the above ANOVA was perhaps surprising, given that little planning took place in Experiment 1—a factor we would expect to result in lower success rates in Experiment 1 than Experiment 2. Comparison of the control conditions confirmed that success rates on the two Tower of London versions did not differ: The mean proportion of problems solved correctly in the control condition of Experiment 1 was 66.6% ($SD = 13.9$), and in Experiment 2 it was 67.1% ($SD = 18.4$), $t(58) = 0.36, p = .72$. Possible explanations of the equal success rates in the two experiments are considered below, in Section 2.5.

Next, our attention turned to the private speech results of Experiment 2's control condition: Would there be a correlation between articulatory suppression interference and private speech production for problems of intermediate difficulty? Private speech was produced during 47% of the trials on average ($SD 39$, range 0 to 100). The mean (SD) percentages of trials with private speech for 2-, 3-, 4-, and 5-move problems were 34 (42), 41 (44), 50 (46), and 60 (45), respectively. The percentage of trials with private speech appeared to increase with difficulty level, but

note that trial duration also increased with difficulty level (data not shown). Our measure of articulatory suppression interference was the percentage of trials correct in the articulatory suppression condition minus the percentage of trials correct in the control condition. Thus, a positive figure indicated poorer performance in the articulatory suppression condition than in the control condition. We used this *difference score* in line with previous research on individual differences in articulatory suppression interference (Lidstone, Fernyhough, Meins, & Whitehouse, 2009), but we also calculated a measure of articulatory suppression interference based on *residual scores*, by partialling the control condition performance from the articulatory suppression condition performance. As the correlations using these residual scores produced exactly the same pattern as those using the difference scores, only the latter are shown below.

The correlations between articulatory suppression interference and the proportion of trials with private speech in the control condition for 2-, 3-, 4-, and 5-move problems (with 29 degrees of freedom) were .07, -.10, .47, and .21, respectively (Pearson's correlation coefficients). The largest of these was statistically significant ($p = .01$). As expected, then, the relation between private speech production and interference by articulatory suppression was found for problems of intermediate difficulty only. These results indicate that children who produced more private speech on 4-move problems experienced greater interference from articulatory suppression on these problems, and therefore that articulatory suppression has its detrimental effect on Tower of London performance by suppressing self-directed speech.

2.5 General discussion

The principal aim of the study was to investigate, using the dual task paradigm, whether or not planning relies on self-directed speech in middle childhood. Experiment 1 showed no effect of articulatory suppression on performance of the standard Tower of London. However, this was interpreted as being due to a lack of planning in our sample. Experiment 2 showed that, when participants were forced to plan ahead, suppressing self-directed speech was detrimental to Tower of London performance. The results of Experiment 2 support those of Fernyhough and Fradley (2005), Al-Namlah et al. (2006), and Wallace et al. (2009) in suggesting that planning is achieved with the aid of self-directed speech. These findings are consistent with Vygotsky's (1930-1935/1978; 1934/1987) ideas on the role of speech in cognition, and suggest planning can be considered to be largely verbally mediated in middle childhood. The results are consistent with the view that cognition undergoes a domain-general shift towards verbal mediation during early childhood (Al-Namlah et al., 2006; Fernyhough, 2008).

The reason for the lack of planning in Experiment 1 is unknown. There were instructions to plan ahead, and the participants were told how many moves each problem should take and were only rewarded (with stickers) if they solved the problems in the specified number of moves, emphasising that reaching the goal state in more moves than necessary did not constitute a correct answer. In retrospect, our intuition is that starting each session with 2- and 3-move problems might have contributed to the lack of planning for two reasons. First, the participants perhaps did not get into the habit of planning as the first five problems (of 2 and 3 moves) could quite easily be solved correctly with little advance planning. Second, by the time the

children reached the more difficult problems, they perhaps felt comfortable making mistakes, having achieved a good success rate in the earlier part of the session.

In light of the fact that little planning took place in Experiment 1, it is perhaps surprising that control condition performance equalled that of Experiment 2's control condition.¹ We propose that this can be explained in terms of the fact that, in Experiment 1, the problem-solving activity of the participants was in effect carefully "scaffolded," in that the problems were presented in exact order of increasing difficulty. In terms of performance levels, the helpful effect of this scaffolding probably counteracted the detrimental effect of reducing planning.

We have characterised the procedure used in Experiment 2 as requiring more planning than that used in Experiment 1, but the procedure of Experiment 2 undoubtedly drew more heavily on working memory as well. In our view, however, any concept of planning that requires no memory is of limited value. Memory is surely vital to planning, because tentative and incomplete plans need to be held in mind while they are evaluated and revised (Cohen, 1996). On this view, to conceptualise the version of the Tower of London used in Experiment 2 as requiring a greater degree of planning is appropriate. In any case, the finding that children's performance of this seemingly spatial task was dependent on self-directed speech still stands.

The fact that the Tower of London procedure which elicited little planning was equally affected by articulatory suppression and foot-tapping is reminiscent of a finding from a previous study relating to the general dual task demands of articulatory suppression and foot-tapping in adults (Emerson & Miyake, 2003). As mentioned in this chapter's Introduction, these authors reported that, on a visual task assumed to be nonverbal, articulatory suppression and foot-tapping affected adults'

performance equally. The present study's Experiment 1 results, indicating equal effects of the two secondary tasks, could be interpreted as preliminary evidence that the secondary tasks exert equivalent dual task demands also in children, and that any deleterious effect of articulatory suppression can be attributed to its effect of suppressing self-directed speech. However, the meaning of the trend towards more secondary task errors in the articulatory suppression condition is unclear, and perhaps counters that claim.

Clearer evidence on the issue of whether articulatory suppression has its effect specifically by blocking self-directed speech comes from the combination of the dual task paradigm with the private speech results. As expected, children who produced more private speech during 4-move problems evidenced a greater difference in performance between the articulatory suppression and control conditions. This suggests that the difference in performance between the dual task conditions related to the fact that, in the articulatory suppression condition, self-directed speech was suppressed.

Although we predicted that the relation between private speech and articulatory suppression interference would exist only for problems of intermediate difficulty, we predicted that there would be an effect of articulatory suppression for easy and intermediate problems, but not for the most difficult problems. The rationale was that the most difficult problems would be beyond the children's ability range and therefore private speech (and inner speech) would not be as useful as for the easier problems. In fact, the effect of articulatory suppression did not vary by difficulty level in Experiment 2. Perhaps 5-move problems were within the range at which private speech would improve performance; the correlation between private

speech production and articulatory suppression interference for 5-move problems was positive (.21), though not statistically significant.

Limitations of the present study include the fact that the reason for the paucity of planning in Experiment 1 is unknown. Although a certain amount of planning probably occurred “online” (while moving the disks), the relation between this and advance planning is unknown (see Berg & Byrd, 2002). Similarly, the precise nature of planning as measured by the *How many moves* version of the Tower of London is somewhat underspecified. Owen et al.’s (1995) *How many moves* version, like Shallice’s (1982) original procedure, is sensitive to frontal lobe lesions (Owen et al.), and comparison of functional neuroimaging studies shows that it activates the same neural network as Shallice’s original procedure (Boghi et al., 2006), including the motor and prefrontal areas associated with planning (Baker et al., 1996). However, to our knowledge no study has directly compared the versions, and so it is not possible to go into detail about how they might differ, save for the observation that the *How many moves* version is likely to involve a larger memory component.² Such studies might prove valuable in the future.

Future research could also look at whether or not the reliance of planning on self-directed speech decreases between childhood and adulthood, as suggested by the present study in combination with that of Fernyhough and Fradley (2005), Al-Namlah et al. (2006), and Wallace et al. (all of which found effects in children or adolescents) and Phillips et al. (1999, which found no detrimental effect of articulatory suppression in adults). The difference between Phillips et al.’s and the others’ findings might be explained in terms of the different ages of the participants. Alternatively, it might be an artifact of the differing task demands of the five-disk and three-disk versions of the Tower of London (Berg & Byrd, 2002). To see

whether adults show an effect of articulatory suppression on the three-disk version might therefore be informative.

The present study is, to our knowledge, the first study investigating planning and indeed any executive function in children by documenting the effect of articulatory suppression relative to a control dual task condition. The results were clear: that planning is dependent on self-directed speech in middle childhood. We suggest that the dual task paradigm is a useful tool for the investigation of self-directed speech in childhood, particularly when used in conjunction with the observation of private speech.

Footnotes

¹ We thank an anonymous reviewer for drawing this to our attention.

² We do not consider the present study to have compared the versions because the Experiment 1 procedure did not elicit planning as it has in previous studies.

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Self-Directed Speech in Autism

3.1 Background

If neoVygotskian theory concerning the origin of self-directed speech is correct, children who are not able to experience typical joint activity will not develop self-directed speech typically. Joint activity is difficult for children with autism, among others. Autism is a disorder characterised by a triad of impairments in social functioning, communication, and repetitive and stereotyped behaviours (Wing & Gould, 1979). For our purposes, perhaps the most important characteristics relate to the social domain. Children and adults with autism show a tendency not to orient to social stimuli, including speech (Dahlgren & Gillberg, 1989; Lord, 1995). Between the ages of 1 and 3 years, children with autism are reliably differentiated from children without autism by parental report that they show lack of social reciprocity (Lord, 1995), turntaking (Wimpory, Hobson, Williams, & Nash, 2000), desire for shared enjoyment (Cox et al., 1999; Lord, 1995), and joint attention (Cox et al., 1999; Lord, 1995; Wimpory et al., 2000). Joint attention deficits include a failure to follow another's gaze, and to show and point to objects in order to share attention (as opposed to request things) (Leekam, 2005). These deficits have also been demonstrated in experimental situations (Landry & Loveland, 1988; Leekam, López, & Moore, 2000; Mundy, Sigman, Ungerer, & Sherman, 1986).

3.2 A prediction

In light of these abnormalities, Fernyhough (1996, 2008) predicted that children with autism would have “restricted opportunities for the internalization of dialogue [which would] result in deficits in self-regulatory private speech and inner speech” (Fernyhough, 2008, p. 253). That is, there may be abnormal or absent self-directed speech.

In support of this, a self-reported dearth of inner speech use was found in a systematic study of three adults with Asperger syndrome (Hurlburt, Happé, & Frith, 1994), using an experience sampling and interview technique. The participants reported thoughts primarily or solely in the form of images, which contrasts with findings from studies of typical adults who report frequent verbal imagery. Similarly, Grandin (1995), in her autobiographical account of autism, claims to “think in pictures.” However, given the problems understanding the minds of self and other in autism, and the small number of individuals involved, these introspective reports can only be given the status of preliminary evidence for impairment in self-directed speech. Nevertheless, the paucity of verbal mediation described in these introspective reports was supported by some (but not all) of the experimental studies that followed. These will be considered next.

3.3 Evidence

3.3.1 *Phonological recoding*

Phonological recoding refers to the verbal labelling of pictorial information, either aloud in private speech or silently in inner speech. In a study of phonological recoding, Joseph, Steele, Meyer, and Tager-Flusberg (2005) administered two

versions of a self-ordered pointing task (SOPT) to 5- to 14-year-old children with autism and typically developing controls. The groups were matched on age, verbal IQ, nonverbal IQ, and visual recognition memory. For the SOPT, participants were presented with a number of pictures repeatedly, in a new spatial arrangement each time, and the task was to point to a different picture upon each presentation. The participants therefore had to remember which pictures they had already selected. One version of the task contained pictures that could be encoded verbally and the second contained abstract patterns that could not. The children with autism were impaired relative to controls on the verbal task but not the abstract task; this was not due to impairment in verbal memory as the groups performed equally well on a measure of this. In addition, verbal SOPT performance was correlated with language ability in the control group but not in the autism group. Joseph et al. interpret their results to mean that the children with autism did not spontaneously (covertly) name the pictures to remember their previous choices. In other words, they did not engage in *phonological recoding* of the pictures.

In another study, Whitehouse, Maybery, and Durkin (2006) looked at phonological recoding with more traditional methods—using the *picture superiority effect* and the *word length effect*. The picture superiority effect refers to the fact that, if participants are engaging in phonological recoding, pictures will be more accurately remembered than words, because pictures will be encoded in two ways (visually and verbally) whereas words are assumed to be encoded only verbally. Such an effect should occur only to the extent that participants are using phonological recoding. In Whitehouse et al. (2006, Experiment 1), children with autism demonstrated a smaller picture superiority effect than typically developing

children matched on verbal and nonverbal mental age, suggesting that the children with autism were less likely than controls to recode the pictures phonologically.

As mentioned above, another sign of phonological recoding is the word length effect for pictures, which refers to the fact that, if participants are engaging in phonological recoding, they will remember fewer pictures when the names of the objects depicted by them have several syllables than when they just have one, because it takes longer to rehearse multisyllabic words. Whitehouse et al. (2006, Experiment 2) had the two groups try to remember pictures with labels differing in length, in two conditions. In the *silent condition*, the children were free to use whatever strategy they liked as long as they remained silent, whereas in the *label condition*, they had to overtly name the pictures. In the silent condition, the children with autism showed a smaller word length effect than did the controls, again, suggesting that the children with autism were less likely than controls to spontaneously recode the pictures into words. Having to label the pictures increased the size of the word length effect for the children with autism but not the controls, supporting the assumption that the controls spontaneously engaged in phonological recoding in the silent condition but the children with autism did not. The findings of these two experiments in addition to those of Joseph et al. (2005) suggest that children with autism are less likely than typically developing children to spontaneously recode pictures as words in order to remember them.

Whether or not there is a genuine deficit here was called into question by Williams, Happé, and Jarrold (2008). They looked at the *phonological similarity effect* for pictorial information in children with autism and developmentally delayed controls matched on chronological age, verbal mental age, and nonverbal IQ. The phonological similarity effect refers to the fact that, if pictorial information is being

phonologically recoded, pictures depicting phonologically similar items (e.g., *cat*, *cot*, and *cup*) will be less well-remembered than pictures depicting phonologically dissimilar items (e.g., *bat*, *mop*, and *cow*) because the former are more vulnerable to confusion. The phonological similarity effect for pictorial information is thought to emerge at the verbal mental age of 7 years if inner speech is intact (but see Chapter 6 for a critique of this position). Williams et al. found that children with autism and a verbal mental age of 7 or more showed a phonological similarity effect, in line with results from the control group, and argued that, once the verbal mental age of the participants is taken into account, inner speech is normal among children with autism. Whether or not this negates the previous findings of Joseph et al. (2005) and Whitehouse et al. (2006) is unclear, though, considering that in both of these studies the groups were matched on verbal ability.

However, the major quantitative methods for studying self-directed speech are, as we saw in Chapters 1 and 2, the dual task paradigm and the observation of private speech. At the time of writing the empirical work presented in this chapter, there were only two papers reporting the use of these methods with individuals with autism. These are reviewed next.

3.3.2 Private speech and the dual task paradigm

The first to be published was the third experiment of Whitehouse et al. (2006). The experiment concerned the executive function of task-switching—in this case, alternating between two tasks. The authors found that the task-switching performance of the participants with autism was not disrupted by articulatory suppression to the same extent as that of typically developing children. The findings were interpreted to mean that individuals with autism do not use inner speech to

regulate task-switching. As articulatory suppression interferes with private speech as well, we can take these results to mean that the task-switching of the children with autism was less reliant on self-directed speech than was that of the controls. (The control condition did not have a nonverbal secondary task, a design criticised in Chapter 2 on account of the fact that articulatory suppression exerts a cognitive load in addition to disrupting self-directed speech. However, this is not problematic here for two reasons. First, it has already been established that task-switching is disrupted by articulatory suppression relative to tapping control conditions (see Section 2.2), so the effect of articulatory suppression on task-switching is not entirely due to general cognitive load. Second, Whitehouse et al.'s research questions were different to those of the studies considered in Chapter 2. Specifically, the hypothesis was that children with autism would be better at task-switching under articulatory suppression than would controls. As there is no reason to believe that children with autism would be better than controls at performing two tasks simultaneously, we can attribute a lack of interference by articulatory suppression in this group to a lack of reliance on self-directed speech. Therefore the absence of nonverbal secondary task in the control condition is not inappropriate in this case.)

The private speech of children with autism was investigated by Winsler and colleagues (Winsler, Abar, Feder, Schunn, & Rubio, 2007). They observed the private speech produced by children with autism and typically developing controls while completing two executive tasks, the Wisconsin Card Sorting Test (WCST) and the Building Sticks Task (BST). The WCST is well known, and is widely understood to involve shifting attentional set. The BST involves building sticks of a specified length from shorter sticks. Items are solvable by one of two strategies, *overshoot* and *undershoot*. The first 20 trials are mostly solvable by overshoot and the next 20 trials

are mostly solvable by undershoot. The BST is therefore similar in some respects to the WCST, in that participants must change their strategy part way through the task. In contrast to Whitehouse et al.'s (2006) findings on self-directed speech, Winsler et al. reported that the children with autism used task-relevant private speech as frequently as the controls. In the autism group compared to the control group, the private speech was as, if not more, useful for task performance.

Therefore, in Winsler et al.'s (2007) study, private speech development seemed to be largely intact in the children with autism. There was less partially-internalised private speech in the autism group than the control group in one of the two tasks, but there was no suggestion that the participants with autism did not use language as frequently or as effectively to mediate their performance. What might explain the difference in findings between these two studies?

3.4 A prediction refined

It is perhaps unlikely that self-directed speech for task-switching (Whitehouse et al., 2006) would be more impaired than self-directed speech for the WCST and BST (Winsler et al., 2007). Presumably the speech for task-switching simply serves to label the next task to be performed (*plus, minus, plus, minus...*) whereas the speech for the WCST and BST is more complex, in that it could be used for the redirection of attention, strategy formation, and hypothesis testing. If differences in the tasks cannot explain the difference in the findings of the two studies, our attention must turn to whether or not there were differences in the participants. Winsler et al. did not report IQ data, but stated that the diagnosis of 61% of the autism group was in fact Asperger syndrome. There is controversy and confusion about the precise differences between high functioning autism and

Asperger syndrome (Leekam, 2007), but the latter is widely regarded as being characterised by relatively intact language skills. In contrast, Whitehouse et al.'s participants with autism had a mean verbal mental age of 18 months less than their chronological age, and a mean nonverbal mental age of 6 months greater than their mean chronological age. Given that having superior nonverbal skills relative to verbal skills (a NV>V profile) is quite common in the autistic population, and that this profile is thought by some to represent a special cognitive phenotype (Joseph, Tager-Flusberg, & Lord, 2002), we sought to test the hypothesis that self-directed speech is particularly impaired in children who have both autism and a NV>V profile. As described in the following paper, it seemed plausible that children with autism with relatively poor verbal skills *and* proficient nonverbal skills might be particularly predisposed to not developing self-directed speech for task-switching.

What follows is a reanalysis of Whitehouse et al.'s (2006) task-switching data, testing the hypothesis that NV>V profile moderates the impairment in self-directed speech in autism.

3.5 The moderating effect of cognitive profile

The following material is from: Lidstone, J. S. M., Fernyhough, C., Meins, E., & Whitehouse, A. J. O. (2009). Brief report: Inner speech impairment in children with autism is associated with greater nonverbal than verbal skills. *Journal of Autism and Developmental Disorders*, 39, 1222-1225.

(Please note that the term *self-directed speech* is not used in this paper because *inner speech* was the term used by Whitehouse et al., 2006. Although articulatory suppression interferes with both private speech and inner speech, and an inner speech impairment is likely to be preceded by private speech impairment

earlier in development, the term *inner speech* is used for the sake of consistency with the original report of the data.)

3.5.1 Abstract

We present a new analysis of Whitehouse, Maybery, and Durkin's (2006, Experiment 3) data on inner speech in children with autism (CWA). Because inner speech development is thought to depend on linguistically-mediated social interaction, we hypothesised that children with both autism and a nonverbal>verbal (NV>V) skills profile would show the greatest inner speech impairment. CWA and typically developing controls ($n = 23$ in each group) undertook a timed mathematical task-switching test, known to benefit from inner speech use. Participants completed the task with and without articulatory suppression (AS), which disrupts inner speech. The hypothesis was supported: AS interference varied with cognitive profile among CWA but not among controls. Only the NV>V autism group showed no AS interference, indicating an inner speech impairment.

3.5.2 Introduction

Children with autism (CWA) are often characterised by an uneven cognitive profile, with substantial differences in the verbal and nonverbal abilities of affected children. The dissociation of verbal and nonverbal skills is uncommon among developmental disorders, leading researchers to explore discrepancies between these abilities as a way of understanding more about the cognitive phenotype of autism.

Perhaps the most common profile associated with CWA is that characterised by greater nonverbal than verbal ability (NV>V; Joseph, Tager-Flusberg, & Lord, 2002). The frequency with which this profile is observed suggests that individuals

with a NV>V profile may comprise an aetiologically meaningful subgroup of autism. Indeed, this profile, as defined by significantly superior nonverbal IQ compared to verbal IQ on the Differential Ability Scales (Elliot, 1990), has been shown to be associated with greater severity of the social symptoms of autism (Joseph et al., 2002), as well as abnormally large head circumference (Deutsch & Joseph, 2003) and brain volume (Tager-Flusberg & Joseph, 2003).

This research takes on added interest when it is interpreted within the context of experimental (e.g., Kana, Keller, Cherkassky, Minshew, & Just, 2006) and introspective (Grandin, 1995; Hurlburt, Happé, & Frith, 1994) reports that visual representation plays a disproportionately prominent role in the way that people with autism process information. This contrasts with studies suggesting that, in normal adults, cognition is more often verbal in nature. Some of these rely on introspective reports (Hurlburt et al., 1994), but most research on this topic employs dual task methodology. Here, the use of internal verbalising (or inner speech) is measured by analysing the effect of preventing it, by means of irrelevant articulation (articulatory suppression, AS) during the primary task. The performance of typical adults on the executive tasks of strategic planning (Baldo et al., 2005) and task-switching (e.g., Baddeley, Chincotta, & Adlam, 2001), has been shown to be compromised with the addition of AS.

According to one prominent view, the development of inner speech depends on the gradual internalisation of linguistically-mediated social interactions over the course of childhood, resulting in cognitive processes that are mediated by language (Vygotsky, 1934/1987). Therefore we would predict that disrupted inner speech development would follow from impoverished experiences of social interaction and/or language difficulties (Fernyhough, 1996), both of which characterise CWA.

Intriguingly, a recent study of CWA by Whitehouse, Maybery, and Durkin (2006, Experiment 3) found a reduced effect of AS on a timed mathematical task-switching test relative to typically developing controls, suggesting that CWA may not use inner speech to the same extent as the general population.

We hypothesised that children who had poor language skills in addition to autism would experience the greatest disruption in inner speech development, especially if they had effective nonverbal skills for achieving goals, i.e., a NV>V profile. To test this hypothesis, we analysed data of Whitehouse et al. (2006), Experiment 3, with respect to cognitive profile.

3.5.3 Method

3.5.3.1 Participants

Participants were 23 boys with autism and 23 typically developing boys from Perth, Western Australia. Each child with autism had been diagnosed under DSM-IV guidelines, and a random 50% had their diagnosis confirmed with the Autism Diagnostic Interview—Revised (Lord, Rutter, & LeCouteur, 1994).

Verbal mental age was measured using the Australian standardised version of the Peabody Picture Vocabulary Test—Version IIIA (PPVT; Dunn & Dunn, 1997) and nonverbal mental age was gauged with Raven’s Standard Progressive Matrices (Raven, Court, & Raven, 1992).

The autism and control groups were each divided into two groups, based upon a predetermined criterion of having a nonverbal age that exceeded verbal age by at least 2.5 years. Three participants, all with autism, obtained outlying discrepancy scores (10.33, 7.58 and -4.92 years) when outliers were defined as

observations more than 1.5 times the interquartile range outside of the upper and lower quartiles. These children were excluded from subsequent analyses.

Mean chronological and mental age scores are shown, by group, in Table 3.1. So that the autism and control groups would be equal in nonverbal mental ages, $F(3, 39) = 2.31$, *ns*, the autism groups were older than the control groups, $F(3, 39) = 11.78$, $p < .001$. Verbal mental age also differed by group, $F(3, 39) = 5.51$, $p < .01$. The verbal mental age of the NV=V autism group was significantly greater than that of the NV>V autism group ($p < .01$), but the NV=V and NV>V control groups did not differ significantly in this way ($p > .50$). The implications of the fact that the NV>V autism group had the lowest language level are tested in the Results section.

3.5.3.2 Procedure

Participants were given mathematical problems, with function and equal signs omitted (e.g., $4 - 1 = \underline{\quad}$). The first digit for each problem was selected at random, whilst ensuring that the solution would be a single digit. The digit to be added or subtracted was always 1. Each participant completed two sets of problems with AS, and two sets in the control condition. In both conditions, participants were asked to complete the problems as if there were alternating plus and minus signs, while a metronome sounded one beat per second. In the control condition, participants were given no instructions other than to complete the problems as quickly and accurately as possible. In the AS condition, participants were also asked to repeat the word *Monday* in time with the metronome. There were 20 problems in each set. One set was completed for each condition in each of two sessions, which were conducted roughly 14 days apart. The order of presentation, which was the same for all participants, was counterbalanced across sessions.

Table 3.1*Descriptive Statistics*

	Autism		Control	
	NV = V (<i>n</i> = 12)	NV > V (<i>n</i> = 8)	NV = V (<i>n</i> = 15)	NV > V (<i>n</i> = 8)
Chronological age ¹	11;4 (2;2) _a	10;5 (1;7) _a	8;4 (1;0) _b	8;4 (0;8) _b
Nonverbal age ¹	11;3 (2;0) _a	12;3 (2;0) _a	10;7 (1;2) _a	11;9 (1;1) _a
Verbal age ¹	10;11 (2;11) _a	7;9 (1;4) _b	9;8 (1;4) _{a,b}	8;5 (0;9) _b
Time taken in the control condition (s)	75.3 (45.3) _a	72.5 (36.8) _a	73.0 (20.4) _a	94.8 (28.3) _a
Number of task-switching errors in the control condition (out of 20)	1.3 (1.5) _a	1.1 (1.1) _a	1.3 (1.0) _a	0.9 (0.8) _a

Notes.

All figures are *M* (*SD*). Means in the same row that do not share subscripts differ at $p < .05$ on the Scheffé test.

¹ In years; months.

Mean time taken to complete the lists and the total number of task-switching errors (out of 20) were recorded. For errors that could be interpreted as alternation errors, *consequential marking* was employed to avoid unfair penalties: If a child had subtracted when they should have added, or vice versa, but then resumed alternating, only one error was recorded.

3.5.4 Results

As shown in Table 3.1, performance in the control condition did not vary by group in terms of response times, $F(3,39) = 0.88$, *ns*, or task-switching errors, $F(3,39) = 0.22$, *ns*.

The effect of AS on response times (AS interference) was calculated as the mean time taken in the AS condition minus the mean time taken in the silent condition, so that a more positive number denoted greater AS interference.

A 2×2 (Diagnostic Group [autism, control] \times Cognitive Profile [NV>V, NV=V]) ANCOVA, with chronological age, verbal age, and nonverbal age as covariates, revealed no effect of cognitive profile on AS interference, $F(1, 36) = 2.30$, *ns*, $\eta_p^2 = .06$. There was, however, a main effect of diagnostic group, $F(1, 36) = 4.75$, $p = .04$, $\eta_p^2 = .12$, which was qualified by a significant interaction with profile type, $F(1, 36) = 5.14$, $p = .03$, $\eta_p^2 = .13$. Adjusted means are shown in Figure 3.1.

Two further ANCOVAs explored the effect of cognitive profile on AS interference within each diagnostic group (with the covariates as above). There was an effect of cognitive profile in the autism group, $F(1, 15) = 11.33$, $p < .01$, $\eta_p^2 = .43$, but not in the control group, $F(1, 18) = 1.01$, $p = .33$, $\eta_p^2 = .05$. Thus, amongst the children with autism, AS interference was significantly lower for participants with a NV>V profile than those with a more even cognitive profile.

One-sample *t*-tests comparing AS interference to zero showed that the only group to show no significant AS interference was the autism group with the NV>V profile, $t(7) = 0.19$, $p = .86$ (for all other groups, $p < .05$).

Next, we investigated the possibility that these results could be explained in terms of group differences in the effect of speed of performance on accuracy (speed–accuracy trade-offs). AS interference was calculated in terms of task-switching

errors, as the mean number of errors in the articulation condition minus the mean number of errors in the silent condition. A 2×2 (Diagnostic Group [autism, control] \times Cognitive Profile [NV>V, NV=V]) ANCOVA, (covariates as above), revealed no main effect of diagnostic group, $F(1, 39) = 0.33, ns$, or profile type, $F(1, 39) = 0.66, ns$, and no interaction, $F(1, 39) = 0.33, ns$. Therefore the group differences in the response time AS interference effect (described above) cannot be explained in terms of speed–accuracy trade-offs.

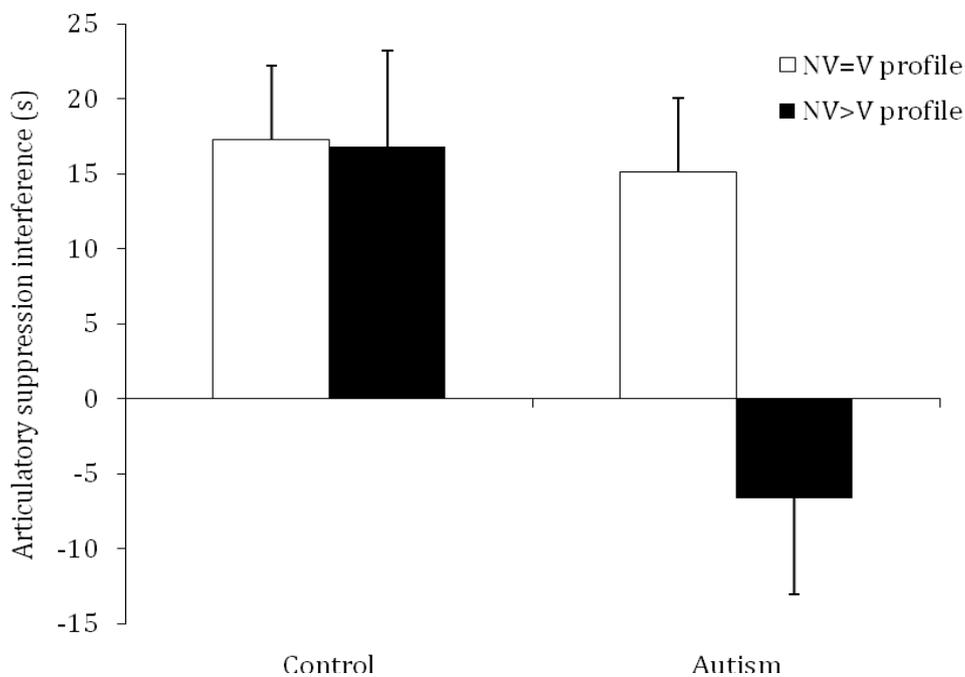


Figure 3.1. Articulatory suppression (AS) interference by group (adjusted means). Error bars represent *SEM*.

Finally, we considered the implications of the fact that the NV>V autism group had the lowest language level of the four groups, by investigating the possibility that AS interference (in terms of response times) could be predicted by language level alone, either in the autism group or in the sample as a whole. The

correlation between verbal mental age and AS interference was not significant either in the autism group, $r(19) = .17, p = .48$, or in the whole sample, $r(42) = -.08, ns$. These correlations did not increase in size when chronological age was partialled out, $r_p(17) = .16$ and $r_p(40) = .07$ respectively, both *ns*. Therefore the lack of AS interference in the NV>V autism group cannot be explained in terms of language level alone: Both verbal and nonverbal ability are needed to explain variation in susceptibility to AS.

3.5.5 Discussion

The analyses reported here show reduced AS interference on a mathematical task-switching test for the autism groups compared to the control groups, consistent with the original report of the data (Whitehouse et al., 2006, Experiment 3). However, further analysis identified this effect to be driven solely by the individuals with a NV>V profile, who showed no interference on task-switching with the addition of AS.

The significant main effect of diagnostic group suggests that the CWA were, on average, less reliant on inner speech in the task-switching paradigm. The presence of the Diagnostic Group \times Cognitive Profile interaction, however, points to the need to refine the view of a simple association between autism and inner speech impairment. Specifically, a NV>V profile appears to interact with autism in producing an inner speech impairment. Poor verbal skills relative to nonverbal skills, combined with the presence of autism, might represent a double blow to inner speech development.

From a Vygotskian perspective, relatively weak verbal skills and the social-interactive atypicalities that characterise autism can both be seen as factors

preventing participation in the type of linguistically-mediated social interactions on which inner speech development is thought to depend. The present findings are therefore in line with evidence from studies on typically developing children that relatively impoverished social interaction and verbal abilities can affect the development of verbal mediation (e.g., Al-Namlah, Fernyhough, & Meins, 2006).

It may be that the children in question both experience barriers to inner speech development *and* have at their disposal nonverbal cognitive strategies, of the sort described in the qualitative accounts of Grandin (1995) and Hurlburt et al. (1994). A notable result here is that the children with both autism and a NV>V profile, although appearing not to use inner speech, performed just as well as the other three groups in the control condition. It is unclear how this was achieved, but one possible nonverbal strategy for task-switching is to “label” the two tasks with spatial representations or motor movements rather than words. Although this task-switching test seemed to be amenable to nonverbal strategies for the participants with both autism and a NV>V skills profile, we would expect a tendency not to use inner speech to have deleterious effects on functioning in the real world, most notably for executive functioning (Baddeley et al., 2001; Baldo et al., 2005) and social understanding (Fernyhough, 2008). The extent to which inner speech abnormalities could explain such impairments in NV>V autism is a matter for future research.

Although we interpret the results in terms of the possible effect of cognitive profile on inner speech development, an alternative possibility is that NV>V profile and reduced inner speech use are not directly functionally related but, rather, have a common cause. Whatever the explanation for the relation, these findings are consistent with previous research suggesting individuals with a NV>V profile

comprise an aetiologically meaningful subgroup of autism (Tager-Flusberg & Joseph, 2003), and add reduced inner speech use to the list of what is known about this subgroup.

That inner speech impairment was found for only a subgroup of participants with autism might account for previous contradictory findings on inner speech in autism. For example, the two other experiments in Whitehouse et al.'s (2006) paper indicated that CWA are less likely than controls to use inner speech to remember pictures, whereas Williams, Happé and Jarrold (2008) report a study in which no such difference was found. Another study looked at the overt speech of CWA while performing two executive tasks (the Building Sticks Task and the Wisconsin Card Sorting Test), and found that they were just as likely as typically developing controls to talk to themselves in task-relevant ways (Winsler, Abar, Feder, Schunn, & Rubio, 2007). The present results suggest that contradictory findings might be explained by differences in the composition of the autism samples. Although all the papers contain information on the participants' verbal ability scores, their IQ profiles are unreported. We suggest that future studies of inner speech in autism consider NV>V profile as a moderating variable.

Finally, it should be noted that this is a relatively small study, in which we relied upon single measures of verbal and nonverbal mental age. Nevertheless the clear findings indicate that associations between cognitive profile and inner speech development in autism deserve further research.

- End of published material -

3.6 Comments

3.6.1 A model of links between the NV>V profile and impaired self-directed speech

In the paper it was argued that the social impairment of autism, which interferes with the ability to take part in verbally-mediated joint activity, would produce self-directed speech impairment when it is accompanied by an imbalance in verbal and nonverbal abilities which biases children away from using self-directed speech. This scenario is depicted in the bottom half of Figure 3.2. In addition to this, the NV>V profile and self-directed speech impairment might be linked by a more “physiological” route. It is fairly well established that the NV>V profile is associated with macrocephaly (Deutsch & Joseph, 2003; Lainhart et al., 2006; Tager-Flusberg & Joseph, 2003). Vaccarino and Smith (2009) suggest that macrocephaly in autism is caused by dysregulation of fibroblast growth factor (FGF) pathways during neural development. They cite as evidence the fact that macrocephaly in autism is particularly pronounced in the medial prefrontal and temporal cortex, two areas particularly dependent on fibroblast growth factors (FGFs) for their development, and that genes associated with molecules that work downstream of FGF have been implicated in autism. FGFs bind to receptor tyrosine kinases, and these pathways control processes related to macrocephaly, such as cell survival and cell size, and processes related to connectivity between brain regions, such as the formation and pruning of axons, dendrites, and synapses. Vaccarino and Smith therefore suggest that, in some cases of autism, dysregulation of these pathways could produce both

macrocephaly and an excess of local circuit neurons coupled with a lack of long range pyramidal neurons—or *structural underconnectivity*.

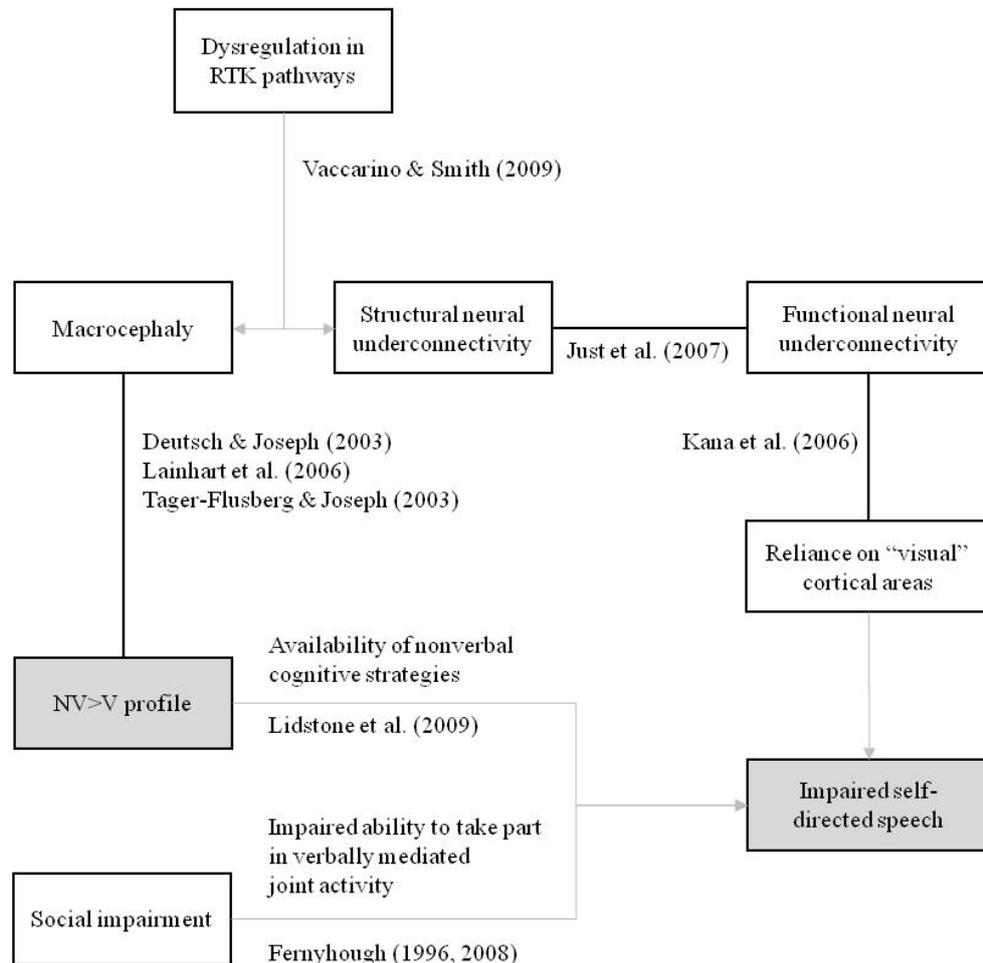


Figure 3.2. Routes by which the NV>V profile and impaired self-directed speech might be linked in autism. Bold black lines represent empirically supported relations. Thin grey lines represent causal theoretical relations. RTKs = receptor tyrosine kinases.

Elsewhere it has been suggested that underconnectivity is the physiological basis of “thinking in pictures” in autism (Kana et al., 2006). Kana et al., in a functional neuroimaging study, had adults with and without autism process sentences

that were high in imagery demands (such as *True or false: "A 6 can be rotated to make a 9"*) and sentences that were low in imagery demands (such as *True or false: "Animals and minerals are both alive, but plants are not"*). They found that, in both the high and low imagery conditions, the cortical areas underlying language and spatial processing were not as well synchronised in the participants with autism as in controls: There was evidence of functional underconnectivity between frontal and parietal areas in the autism group. Furthermore, individual differences in measures of functional and structural underconnectivity were related in the autism group (see also Just, Cherkassky, Keller, Kana, & Minshew, 2007). Functional underconnectivity in the autism group was accompanied by an over-reliance (compared to controls) on parietal areas underlying visual imagery and an under-reliance (compared to controls) on areas associated with verbal rehearsal (the left angular gyrus, the left inferior frontal gyrus, and the left middle frontal gyrus). These group differences were found in the low imagery condition, but not in the high imagery condition, suggesting that the participants with autism were using a "high imagery" strategy in both conditions. That is, the participants with autism appeared to be using visual imagery to support their performance when it was not necessary in the control group.

It is not known whether individual differences in functional underconnectivity among individuals with autism would be associated with greater "visual" processing as measured by cognitive tasks, and indeed it has not been demonstrated that greater structural underconnectivity is associated with macrocephaly, but, as described above, there are theoretical reasons for suspecting these links. If they are found in the future, there would be a second route by which NV>V profile and impaired self-directed speech might be linked (see Figure 3.2). These two routes are not mutually exclusive and might work in parallel.

3.6.2 *Subsequent findings*

Perhaps the most notable findings on self-directed speech in autism that have been published since the paper shown above are those of Wallace, Silvers, Martin, and Kenworthy (2009), and Holland and Low (2010). The latter is a multistudy paper in which Whitehouse et al.'s (2006) task-switching results were replicated: There was no effect of articulatory suppression on task-alternating among children with autism, whereas typically developing controls' performance was slower under articulatory suppression than under normal conditions. As in Whitehouse et al. (2006), the children with autism were as proficient at task-switching as the controls in the control condition, indicating that whatever strategy they were using was successful. (No moderating variables, such as verbal mental age or NV>V profile, were considered.) Holland and Low, in Experiment 2, consider the possibility that the children with autism were using visual-spatial strategies to achieve efficient task-switching. The participants engaged in a visual-spatial suppression task, which involved tapping four blocks in a specified pattern with their non-dominant hand, while task-switching. The groups' performance was affected equally. It is possible, though, that the children with autism were able to use inner speech when forced (by having their usual strategy suppressed), especially as they had excellent language skills (with a mean verbal mental age, measured in terms of receptive vocabulary, of 11 years; 5 months compared to a mean chronological age of 10;9). Therefore it is still not clear if visual-spatial strategies were at the root of the task-switching success of the children with autism as a replacement for self-directed speech.

In Experiment 3 (Holland & Low, 2010), the participants completed a planning task, the Tower of Hanoi, in three conditions: with articulatory suppression,

with the visual-spatial suppression task, and with no secondary task (control condition). Performance in terms of accuracy was not affected by either secondary task in either group. However, the controls' performance was slower in the articulatory suppression condition than in the control condition, whereas, in the autism group, the time taken to complete the problem was unaffected by articulatory suppression. The fact that there was only one trial in each condition underlines the importance of seeing whether or not this finding is replicated.

Interestingly, Wallace et al. (2009) also chose to study self-directed speech in autism using articulatory suppression and a planning task—this time the Tower of London—with adolescents rather than children. The participants completed four problems with articulatory suppression, and four problems with no secondary task (with the condition order counterbalanced). The performance of the controls, in terms of the number of moves required to reach the solution, was detrimentally affected by articulatory suppression, whereas the performance of the participants with autism was not. The results were interpreted as suggesting that inner speech is impaired in autism. However, the Group \times Condition interaction was not statistically significant ($p = .30$), suggesting that we cannot be sure that the groups were affected by articulatory suppression differently: this pattern of findings might well have occurred by chance.

In summary, these two studies using the dual task paradigm (Holland & Low, 2010; Wallace et al., 2009) obtained somewhat unclear results. Perhaps more conclusive findings would have been obtained had moderating variables such as NV>V profile been considered.

One subsequent paper that did consider NV>V profile as a moderating factor was that of Williams and Jarrold (2010), who report a reanalysis of their data on the

phonological similarity effect for pictorial information in children with autism and developmentally delayed controls. The original finding was that children with autism with a verbal mental age of 7 or more showed a phonological similarity effect, in line with results from the control group (Williams et al., 2008) suggesting that phonological recoding, or using self-directed speech to remember pictorial information, emerges in line with verbal mental age in autism. The reanalysis (Williams & Jarrold, 2010) confirmed that the participants with a verbal mental age of more than 7 showed a phonological similarity effect as normal, regardless of autism diagnosis and cognitive profile. The development of phonological recoding thus appears to be intact in autism when verbal mental age is accounted for, and cognitive profile explains no additional variance.

The discrepancy between the findings of Lidstone et al. (2009) and Williams and Jarrold (2010) regarding the status of cognitive profile as a moderating variable in self-directed speech use might stem from the fact that the subject of the two studies was two different types of verbal mediation—the verbal mediation of task-switching and the verbal mediation of short-term memory respectively. These different types will be compared and contrasted in some detail in the General Discussion (Section 6.2.1) in order to consider whether or not this is a significant enough difference to explain the discrepancy in findings (and to see if the development of verbal mediation can be considered to be *domain-general*, see Chapter 5).

3.7 Concluding remarks

In the brief report, only children with both autism and a NV>V profile showed a lack of self-directed speech use during task-switching, operationalised as a

lack of interference by articulatory suppression. There was no difference in the effect of articulatory suppression on task-switching between the typically developing children with a NV>V profile and the typically developing children with a NV=V profile, suggesting no effect of language proficiency on self-directed speech development. However, the mean verbal mental age of the typically developing NV>V group ($M = 8;4$, $SD = 0;8$) was commensurate with its mean chronological age ($M = 8;5$, $SD = 0;9$). It is reasonable to suspect that the situation would be different where there is *language impairment* (a NV>V profile, with verbal mental age significantly lower than chronological age). Specifically, we hypothesised that language impairment would be enough to cause a self-directed speech deficit or delay, even in the absence of autism. This is the hypothesis tested in Chapter 4.

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Self-Directed Speech in Specific Language Impairment

This chapter comprises the following manuscript: Lidstone, J. S. M., Meins, E., & Fernyhough, C. (2010). *Verbal mediation of cognition in children with specific language impairment*. Manuscript submitted for publication.

4.1 Abstract

Private speech and inner speech are thought to be functionally important for children's and adults' cognition, but they have not been studied systematically in children with Specific Language Impairment (SLI). Participants were 21 children with SLI (7 to 11 years old, expressive or receptive verbal IQ ≤ 75 , nonverbal IQ ≥ 84) and 21 age- and nonverbal IQ-matched controls. Participants completed three sets of Tower of London problems: one with no dual task (private speech condition), one with articulatory suppression, and one while foot-tapping (control condition). The order of the latter two conditions was counterbalanced. Participants also completed a digit span task. There was no group difference in the susceptibility of Tower of London performance to articulatory suppression, but the private speech of the SLI group was less internalised than that of the controls on both tasks. The findings suggest that children with SLI experience a significant delay in the development of private speech, but that their speech production is effective for Tower of London performance in middle childhood. Findings are discussed with reference to the interpretation of the nonlinguistic deficits associated with SLI, and in terms of clinical implications.

4.2 Introduction

In early and middle childhood, children often talk themselves through their activities, producing *private speech* to regulate their thought and behaviour. In the preschool years, private speech is usually overt, but in middle childhood, it is more likely to take the form of covert muttering and whispering, and silent, verbal lip movements (see Winsler, 2009). This shift toward covert private speech is thought to reflect the gradual internalisation of private speech to form *inner speech*, or silent verbal thought (Vygotsky, 1934/1987). Private speech and inner speech together are hereafter referred to as self-directed speech (Figure 4.1).

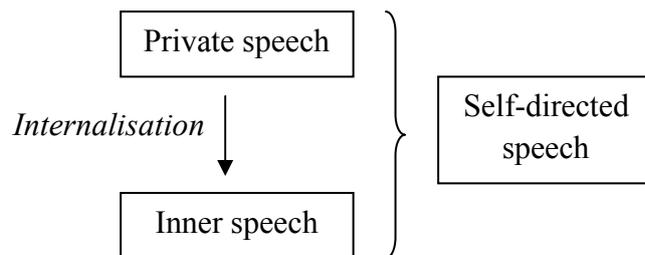


Figure 4.1. Conceptual relations between private speech, inner speech, and self-directed speech.

Vygotsky (1934/1987) contended that, by middle childhood, goal-directed thinking and self-regulation are fundamentally verbal in nature. In support of this, there are positive associations between children's private speech production during cognitive tasks and their performance of those tasks, in the areas of general problem-solving (Behrend, Rosengren, & Perlmutter, 1989, 1992), executive function (Fernyhough & Fradley, 2005; Müller, Zelazo, Hood, Leone, & Rohrer, 2004; Winsler, Diaz, & Montero, 1997) and schoolwork (Bivens & Berk, 1990).

Associations between aspects of private speech production and other abilities, such as self-regulation (Winsler, De León, Wallace, Carlton, & Willson-Quayle, 2003) and theory of mind (Fernyhough & Meins, 2009), also support the idea that cognition and self-regulation are dependent on the online use of language.

Experimental evidence for this claim comes from studies which assess the effect on task performance of preventing self-directed speech, using the *dual task paradigm*.

Participants are asked to engage in *articulatory suppression*, such as repeating a word, and this has been shown to impair performance on several tasks, such as the Tower of London in children (Lidstone, Meins, & Fernyhough, 2010) and adolescents (Wallace, Silvers, Martin, & Kenworthy, 2009), and the Wisconsin Card Sort Test (Baldo et al., 2005) and Raven's Matrices (Kim, 2002) in adults. In sum, many types of cognition and self-regulation come to rely on self-directed speech during the course of typical development.

How does language come to have this self-regulatory function? Vygotsky (1930-1935/1978) proposed that, by participating in linguistically mediated joint activity, a child creates (with their interactional partner) a dialogue that can be internalised to form self-regulatory speech. As Fernyhough (2010) explains, words which a child has used to regulate the thought and behaviour of others, or which others have used to regulate the child's thought and behaviour, become employed in regulating the thought and behaviour of the child. According to this account, language is a crucial part of our explanation of human self-regulation, with biologically-specified executive capacities being fundamentally transformed by their interaction with language, creating a new functional system.

This neoVygotskian view is supported by studies revealing social influences on the development of self-regulation (Kochanska, Murray, & Harlan, 2000; Landry,

Miller-Loncar, Smith, & Swank, 2002; Lengua, Honorado, & Bush, 2007). For example, in one study (Lengua et al., 2007), children of mothers who were observed to scaffold their behaviour effectively in a variety of contexts at one timepoint showed greater gains in effortful control over the next 6 months. Although no distinction was made between verbal and nonverbal maternal behaviours in this study, many of the scaffolding behaviours presumably involved speech. It is also pertinent to this discussion that the association showed some specificity: It was specifically scaffolding behaviours and not other maternal behaviours like maternal warmth or negativity that predicted changes in the children's effortful control. In another study, in which only verbal maternal behaviours were recorded, Landry et al. (2002) found that maternal scaffolding of children's behaviour in free play at age 3 years predicted executive functioning at age 6, though indirectly through verbal and nonverbal ability.

This shift from linguistically-mediated other-regulation to linguistically-mediated self-regulation has also been demonstrated on a microdevelopmental basis, during collaborative problem-solving sessions between adults and children. Winsler et al. (1997) present a microdevelopmental analysis of children's performance on a selective attention task during a session in which an experimenter would verbally scaffold their activity when needed. Key findings were that, after successful scaffolding, the children consistently used private speech, and more so than if no scaffolding had been given. Furthermore, after scaffolding, children were more likely to succeed if they used private speech than if they were silent. This relation between private speech and performance did not exist for trials following a lack of scaffolding. Therefore children's private speech (or linguistically-mediated self-regulation) seemed to mediate the link between linguistically-mediated other-

regulation and their increasing competence on this executive task. This is one of several studies linking adult behaviour in joint activity to children's subsequent private speech production (Diaz, Winsler, Atencio, & Harbers, 1992; Winsler, Diaz, McCarthy, Atencio, & Adams Chabay, 1999).

This research on the importance of language for cognition, and the developmental origins of its role, raises the question of what happens in Specific Language Impairment (SLI). SLI is diagnosed when a child shows a significant failure of normal language development that is not attributable to environmental deprivation, hearing loss, focal brain injury, or any other neurodevelopmental disorder. Children with SLI exhibit problems with phonology, morphology, syntax, and semantics to varying degrees and often have impairment in both expressive and receptive language (see Leonard, 2000). Whereas, in typical development, language takes on a self-regulatory function during the preschool years, SLI in preschool age children would presumably present a two-fold barrier to the development of self-directed speech. First, expressive language impairment might limit the utility of speech in cognition. Second, receptive language impairment might limit their comprehension of the verbal scaffolding provided by their interactional partners.

These factors might contribute to delayed self-directed speech development in SLI, such that its development follows the typical trajectory, but occurs at a slower rate than in typically developing children. Alternatively, an early language delay might throw the development of self-directed speech off course in a more fundamental manner. This might manifest as a tendency not to use language for cognition (Sturn & Johnston, 1999). Even if children with SLI do use language for cognition, though, we might find that their self-directed speech is less helpful than that of typically developing children. According to Diaz and Berk (1995), the

functional connection between speech and action is not a given but, rather, an outcome of development. Therefore, self-directed speech that develops later than in typical development might not have the same influence over performance as it does in typical development. In addition, an expressive language impairment might render speech ineffective or even counterproductive in directing thought. In sum, there might be a delay in the development of self-directed speech in SLI, or alternatively, deviance in its development, the latter manifesting as either a tendency not to use language for thought, or in its ineffectiveness for facilitating thought.

If language impairment causes either delay or deviance in the development of self-directed speech, this might go some way towards explaining the documented deficits in nonlinguistic tasks seen in SLI. Children with SLI exhibit poorer performance than age-matched controls in a number of areas, including Piagetian conservation (Mainela-Arnold, Evans, & Alibali, 2006), some mathematical abilities (Donlan, Cowan, Newton, & Lloyd, 2007), some visual-spatial tasks (Akshoomoff, Stiles, & Wulfeck, 2006; Bavin, Wilson, Maruff, & Sleeman, 2005; Windsor, Kohnert, Loxtercamp, & Kan, 2008), and some (Bishop & Norbury, 2005a; Finneran, Francis, & Leonard, 2009; Im-Bolter, Johnson, & Pascual-Leone, 2006) but not all (Bishop & Norbury, 2005b; Im-Bolter et al., 2006; Weckerly, Wulfeck, & Reilly, 2001) executive functions. Children with SLI have also been found to show poorer emotion regulation (Fujiki, Brinton, & Clarke, 2002) and theory of mind (Farrant, Fletcher, & Maybery, 2006) than their peers. Several authors (Bishop & Norbury, 2005a; Fujiki, Spackman, Brinton, & Hall, 2004; Johnston, 1994; Leonard, 2000; Mainela-Arnold et al., 2006) have suggested that such deficits might be at least partly due to the effect of language impairment on the verbal mediation of cognition.

Despite the interest in characterising nonlinguistic deficits as the consequence of language impairment, there is to our knowledge only one study of language-for-thought in individuals with language impairment. Sturn and Johnston (1999) observed preschoolers with language impairment and matched controls completing a construction task, and recorded their overt speech. Because the task was completed in pairs, the authors did not limit their analysis to private speech but considered all problem-solving speech, both private and social, to be relevant to their investigation of the extent to which preschoolers with language impairment would use language to facilitate thought. The children with language impairment produced less problem-solving speech than the controls, but they also produced less task-irrelevant speech, rendering the meaning of the reduced rate of problem-solving speech unclear. One interpretation of the results is that there was no specific failure to use language for thought in preschoolers with language impairment. Another is that there was a depression in their use of task-relevant speech that was related to (and probably resulted from) their overall difficulty with language.

In the preschool years, a tendency not to use task-relevant private speech could indicate a failure in its development or, alternatively, just a delay in its emergence. In middle childhood, however, we would expect a delay in private speech development to manifest itself as a lesser degree of internalisation in comparison to age-matched controls, independently of any difference in the rate of private speech production. Deviance in the development of self-directed speech, on the other hand, could be tapped using the dual task paradigm mentioned above: If children with SLI have a reduced propensity to use language for cognition, or if they use language as frequently but less effectively than controls, their performance on

cognitive tasks should be less susceptible to articulatory suppression than that of controls.

To test these hypotheses, we investigated performance on a spatial planning task, the Tower of London (ToL), in children with SLI and in age- and nonverbal IQ-matched typically developing controls. Participants completed problems under normal conditions, and in two dual task conditions: one in which they engaged in articulatory suppression to suppress the use of self-directed speech, and the other, in which they engaged in foot-tapping (control condition). We tested for group differences in (a) the internalisation level of the private speech produced, and (b) the susceptibility of performance to articulatory suppression, as reduced susceptibility in the SLI group would indicate either a relative lack of self-directed speech or its ineffectiveness in supporting ToL performance.^{1,2}

The participants also completed a digit span task with articulatory suppression and, separately, with foot-tapping, as part of another study (unpublished). Although it was technically possible to compare the groups in terms of the susceptibility of digit span to articulatory suppression (in a manner analogous to that for the Tower of London), we did not consider this informative with respect to the present hypothesis. The reason is that any group difference could be explained solely in terms of verbal short-term memory: Children with SLI have impaired phonological short-term memory (see Leonard, 2000), which would result in impaired digit span relative to age-matched controls while foot-tapping, when rehearsal of the content of the phonological store is possible. In contrast, articulatory suppression would inhibit rehearsal of the digits, so group differences in digit span would be reduced under articulatory suppression. Therefore a group difference in the susceptibility of digit span to articulatory suppression would reflect a group

difference in phonological short-term memory processes rather than a group difference in self-directed speech per se. However, in the foot-tapping condition, many participants produced private speech, presenting another opportunity to compare the groups in terms of the internalisation level of private speech. Only the foot-tapping condition is described here.

4.3 Method

4.3.1 Participants

The SLI group consisted of 21 7- to 11-year-old children (16 boys) recruited from specialist teaching facilities, “language units,” in the UK. For a child to be placed in a language unit he/she had to show significant language impairment accompanied by substantially greater nonverbal skills, according to the judgement of a speech and language therapist using standardised assessments. The experimenter for the present study (the first author) measured participants’ nonverbal IQ using the *Recall of Designs* and *Pattern Construction* subtests of the British Ability Scales (BAS-II; Elliott, Smith, & McCullough, 1996). Participants’ receptive language ability was measured using the Test for the Reception of Grammar (TROG-2; Bishop, 2003), and their expressive language ability, using the *Recalling Sentences* subscale of the Clinical Evaluation of Language Fundamentals (CELF-4^{UK}; Semel, Wiig, & Secord, 2006). Participant characteristics are shown in Table 4.1. Each participant with SLI had a standardised expressive or receptive verbal score of 75 or below, and a nonverbal IQ of 84 or above. For all children with SLI, nonverbal IQ outstripped either receptive or expressive verbal IQ by at least 20 points (mean difference between nonverbal IQ and the lower verbal IQ score was 31.1, *SD* 6.4,

range 23 to 52). The mean verbal mental ages of the SLI group were 6 years; 4 months (receptive) and 5 years; 0 months (expressive).

The control group consisted of 21 typically developing children (12 boys) recruited from mainstream classrooms. The groups were matched in terms of age and nonverbal IQ. All controls had standardised expressive and receptive verbal scores of 80 and above.

No participant had a diagnosis of ADHD or autism, a history of hearing problems, or focal brain injury, according to teacher report. The groups did not differ in age, $t(40) = 0.11, p = .91$, or nonverbal IQ, $t(40) = 0.06, p = .96$. There were large group differences in standardised expressive and receptive language scores, $t(39) = 11.47, p < .001$, and $t(38) = 5.85, p < .001$, respectively. The mean verbal mental ages of the SLI group were 6 years; 4 months (receptive) and 5 years; 0 months (expressive). Informed parental consent was obtained for all participants.

Table 4.1

Participant Characteristics

	Age (years; months)	Nonverbal IQ	Expressive language score	Receptive language score
SLI				
<i>M</i> (<i>SD</i>)	9;5 (1;3)	96 (8)	65 (8)	77 (14)
Range	7;2 - 11;6	84 - 110	55 - 75	55 - 102
Controls				
<i>M</i> (<i>SD</i>)	9;4 (1;2)	96 (8)	95 (9)	98 (9)
Range	7;6 - 11;1	84 - 108	80 - 115	81 - 113

4.3.2 Procedure

4.3.2.1 Overview

First, the participants completed one ToL problem set with no dual task, and the digit span procedure. Then two further ToL problem sets were completed: one with articulatory suppression and the other with foot-tapping. The order of the two dual task conditions was counterbalanced. The tasks were completed over two separate sessions, about a week apart. Sessions were video-recorded for later coding of private speech and, for the ToL, response times.

4.3.2.2 Tower of London

There were eight structurally unique problems in each problem set, and the three problem sets were isoforms of each other. In each set, there were two 2-move problems, two 3-move problems, two 4-move problems, and two 5-move problems, presented in a different pseudo-randomised order in each condition. Each problem set also contained three practice problems; these were simple problems of two and three moves that did not duplicate problems in the experimental problem sets.

The standard ToL requires participants to move the balls one at a time to make two configurations match (Shallice, 1982; see Figure 4.2). The present study used a modified version of the ToL designed to encourage participants to make full mental plans (after Owen et al., 1995). For each problem, participants were asked how many moves it would take to make the configurations match. Participants responded by telling the experimenter the number of moves; they were then required to demonstrate the moves they had planned. Only the time between the start of the trial and the verbal response, the planning phase, was coded for private speech in the

condition with no secondary task. Similarly, in the dual task conditions, the secondary tasks were performed only during this planning phase. A trial was scored as correct if the participant both named and demonstrated the minimum number of moves required to make the configurations match.

4.3.2.3 Digit span

The digit span procedure was adapted from Chincotta and Chincotta (1996) and Towse, Hitch, and Hutton (1998). For each trial, participants were presented, on a laptop computer screen, with 2 cm-high digits at a rate of one per second. After the last digit, there was a blank screen for 4 s. Then a question mark appeared, upon which participants were required to name the digits in the order in which they had been presented. Participants performed the secondary task from the start of each trial until the appearance of the question mark. This period was coded for private speech. The trials were organised in blocks of three trials of the same length, starting with trials of two digits. Participants proceeded to the next block if and when they had recalled two sequences of the current length correctly. Digit span scores took into account performance on both correct and incorrect trials, following Towse et al. As digit span performance does not relate to the hypotheses, the scoring is not described further here.

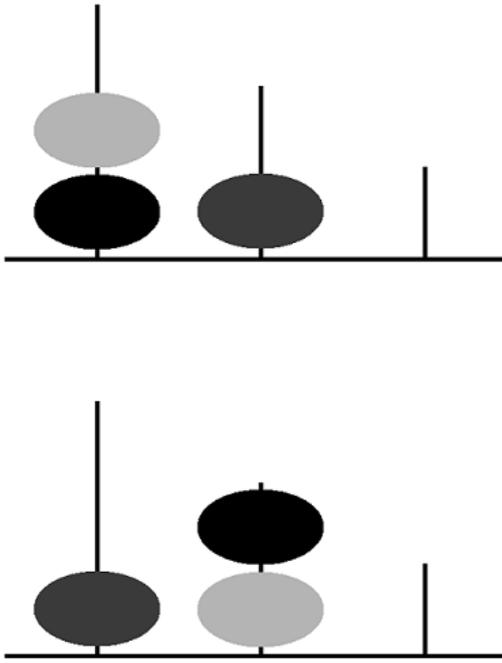


Figure 4.2. Example Tower of London problem: start state (top); goal state (bottom). Actual colours were red, green, and blue.

4.3.2.4 Secondary tasks

Each secondary task was performed at a rate of approximately one response per second. The articulatory suppression task was to articulate the word *Monday*, and the control secondary task involved tapping a foot-pedal connected to a laptop computer. Each tap was accompanied by a beep, generated automatically by the computer. The beeping served as an aural reminder of the task. If there was an error, defined as a gap between taps of 2 s—equal to missing one tap—the computer emitted a warning sound, which ceased when tapping recommenced. The aural reminder of the articulatory suppression task was the experimenter’s articulation of *Monday* in time with that of the child. If the participant made an error, defined as a missed *Monday*, the experimenter reminded her to recommence by uttering her name. Articulatory suppression and foot-tapping have been shown to exert equal

general dual task demands (Emerson & Miyake, 2003), suggesting the only important difference is that articulatory suppression prevents the use of self-directed speech.

4.3.3 Coding of speech

4.3.3.1 Tower of London

Each trial was coded (from the video recordings) as containing speech or no speech. Utterances that were part of the participant's response to the experimenter's question, *How many moves?* were not included, e.g., *Three; I think it's maybe three; Two, I mean, three! Dunno, can I just show you?* The remaining speech was coded as social speech or private speech. Social speech was defined as any full volume speech intended for communication with the experimenter. Communicative intent was identified where the participant involved the experimenter (through physical contact, gaze direction, etc.), during or within 2 s of the utterance (Winsler, Fernyhough, McClaren, & Way, 2005). Examples of social speech are *That one goes there...* and *They're swapped around*. The frequency of social speech was the percentage of trials containing social speech.

Private speech was defined as any speech that did not meet the criteria for social speech. Private speech is traditionally (Winsler et al., 2005) coded according to Berk's (1986) three-level scheme, as *Level 1* (task-irrelevant private speech), *Level 2* (task-relevant, overt private speech), or *Level 3* (external manifestations of task-relevant inner speech, including inaudible muttering and whispering, and silent, verbal lip movements). There were only two task-irrelevant utterances in the present corpus, so these were excluded from analysis. All private speech considered

hereafter is task-relevant. Examples of the private speech produced are: *One, no, one, two, no...*; *That will go there*; *The blue one out of the way*; *This isn't working*; *How many moves...* The frequency of private speech was the percentage of trials containing private speech.

Each private speech utterance was coded in terms of its internalisation level using a new coding scheme, based on Levels 2 and 3 of the traditional coding scheme described above. Two parallel dimensions of covertness were considered: intelligibility (two levels: intelligible, unintelligible) and audibility (four levels: silent verbal lip movements, whispering, muttering, full volume speech). Combining these dimensions produced the following five levels of internalisation:

- 1 Silent verbal lip movements OR Unintelligible and barely audible whispering
- 2 Audible but unintelligible whispering OR Intelligible but barely audible whispering
- 3 Intelligible whispering OR Unintelligible muttering
- 4 Intelligible muttering
- 5 Full volume speech

Internalisation scores were then calculated on a trial-by-trial basis, to parallel the commonly-used trial-based metric of private speech production (Winsler et al., 2005). The internalisation level of a trial was the mean of all the utterances in that trial, e.g., a trial containing two level 2 utterances and one level 3 utterance scored $(2 + 2 + 3) / 3 = 2.33$. A participant's internalisation score for the task was the mean score of all the trials with private speech. Lower scores indicate more internalised private speech.

A second researcher, naïve to the hypotheses and to group membership, independently coded a random 20% of the recordings (four from each group), for the

calculation of inter-rater reliability. For the presence/absence of social speech during a trial, Cohen's $\kappa = 1.00$. For the presence of private speech, $\kappa = .91$. The agreement for the internalisation level of trials' private speech, with a tolerance of 0.5, was 93%, i.e., the researchers' codings differed by more than 0.5 on only 7% of the trials with private speech.

4.3.3.2 Digit span

There was no task-irrelevant private speech or social speech, so each trial was coded from the video recordings as containing task-relevant private speech or no speech. The frequency of private speech and its internalisation level were scored as described above.

A second researcher's codings for a random 20% of the recordings (four from each group) produced a reliability coefficient of $\kappa = .85$ for the presence of private speech. For the internalisation level of private speech, with a tolerance of 0.5, there was 93% agreement.

4.3.4 Analysis

As the internalisation level of individuals' speech is partly a function of their competence at a task (Berk & Spuhl, 1995; Duncan & Pratt, 1997), we needed to take into the account the possibility that the tasks were more difficult for the SLI group than for the control group (almost certainly true of the digit span task, see Leonard, 2000). This was done by calculating a second set of private speech scores. For the modified scores relating to the ToL, for each participant we identified a set of trials on which performance was 50% accurate. For example, if a participant solved correctly both 2-move problems, both 3-move problems, one 4-move problem, and

neither 5-move problem, only the 3- to 5-move problems would contribute to the modified private speech scores. The digit span task ended when the participant answered incorrectly two out of the three trials at any one level of difficulty. Therefore, on the last few blocks of trials administered, the proportion of trials answered correctly was similar for all participants. Thus, the modified private speech scores relating to digit span were based on the last three blocks of trials.

ToL performance in the dual task conditions was quantified in three ways: percentage of ToL trials answered correctly, mean response time, and percentage of trials containing one or more secondary task error.

Three children with SLI were not able to complete the ToL with the secondary tasks. To minimise discomfort, testing was terminated after three experimental trials in each condition. These participants were excluded from analyses of the dual task conditions and, to maintain good group matching, three controls of equivalent age and nonverbal IQ were also excluded. Two other children with SLI did not complete the digit span task: in the first case, because of time constraints, and in the second, because of a difficulty waiting for the question mark to appear before responding. These children and their equivalents in the control group were excluded from the analyses relating to this task.

The distribution of all the variables was explored using Shapiro-Wilk tests, with an α of .01. The private speech variables met the criteria for non-normality (positively skewed). Therefore, for these variables, the Mann Whitney *U* test was used to compare groups. Otherwise, parametric tests were used.

4.4 Results

4.4.1 Preliminary analyses

The percentage of ToL problems solved correctly was lower in the SLI group, $M = 41.8$, $SD = 21.6$, than the control group, $M = 56.5$, $SD = 13.5$, $t(40) = 2.66$, $p = .01$. The mean response time did not differ between groups; SLI $M = 16.2$ s, $SD = 8.8$; controls: $M = 18.0$ s, $SD = 6.4$; $t(40) = 0.54$, $p = .59$. The percentage of ToL trials with social speech was low in both groups, but was higher in the SLI group, $M = 5\%$ ($SD = 7$), than the control group, $M = 2\%$ ($SD = 6$); $U = 160.5$, $p = .04$. The private speech results are shown in Table 4.2. For the ToL, the groups did not differ in total private speech production, $U = 194.0$, $p = .50$. For the subset of ToL trials on which performance was 50%, there were no group differences in private speech production; $U = 213.0$, $p = .85$.

The digit span of the SLI group, $M = 4.0$, $SD = 1.0$, was lower than that of the control group, $M = 4.9$, $SD = 0.7$, $t(38) = 3.17$, $p = .003$. There was no group difference in the frequency of private speech production, either overall, $U = 152.0$, $p = .40$, or for the last three blocks of trials, $U = 173.0$, $p = .82$.

4.4.2 Internalisation scores

Internalisation scores are shown in Table 4.2. For the ToL, the SLI group's private speech was less internalised than that of the control group, both overall, $U = 99.5$, $p = .02$, and for the subset of trials for which performance was 50%, $U = 96.0$, $p = .05$. Similarly, for the digit span task, the SLI group's private speech was less internalised than that of the control group, both overall, $U = 77.5$, $p = .01$, and for the last three blocks of trials, $U = 77.5$, $p = .02$.

Table 4.2***Private Speech Production***

Variable			SLI	Controls
Frequency of private speech (% of trials with private speech)	ToL	All trials	55 (39)	48 (26)
		Subset of trials	54 (41)	53 (32)
	Digit span	All trials	63 (33)	55 (33)
		Subset of trials	65 (35)	63 (37)
Internalisation level	ToL	All trials	2.1 (1.3)	1.4 (0.7)
		Subset of trials	2.2 (1.4)	1.3 (0.8)
	Digit span	All trials	1.4 (0.5)	1.1 (0.1)
		Subset of trials	1.4 (0.4)	1.1 (0.1)

Note. All figures are $M(SD)$. For the Tower of London (ToL), *subset of trials* refers to the subset of trials scoring 50% correct. For digit span, *subset of trials* refers to the last three blocks of trials each participant completed. For private speech frequency on the ToL, $n = 21$ in each group. For private speech frequency on digit span, $n = 19$ in each group. For internalisation scores, n is between 16 and 20 (inclusive).

4.4.3 Susceptibility of Tower of London performance to articulatory suppression

The results from the dual task conditions appear in Table 4.3. Each measure of performance was explored using a 2×2 (Condition [articulatory suppression, foot-tapping] \times Group [SLI, controls]) mixed model ANOVA. For the percentage of ToL trials solved correctly, there was a main effect of condition, $F(1, 40) = 16.34$, $p < .001$, with poorer performance with articulatory suppression than with foot-

tapping. There was neither an effect of group, $F(1, 40) = 1.98, p = .17$, nor a Condition \times Group interaction, $F < 1$.

The same model was used to explore response times. There was no main effect of condition or group, both $F_s < 1$, and there was no Condition \times Group interaction, $F(1, 34) = 1.92, p = .18$.

In the analysis of secondary task error rates, there was a main effect of condition, $F(1, 34) = 7.78, p = .01$, with more articulatory suppression errors than foot-tapping errors. There was no main effect of group, $F(1, 34) = 2.50, p = .12$, or Condition \times Group interaction, $F(1, 34) = 1.73, p = .20$.

Thus there was no Condition \times Group interaction on any measure of performance, indicating no significant group differences in the susceptibility of ToL performance to articulatory suppression. Where the F value for the interaction was more than 1.00, we examined the data more closely for evidence that the susceptibility to articulatory suppression was smaller for the SLI group than the control group. Articulatory suppression decreased the mean response time from 15.3 to 14.2 s in the SLI group, $t(17) = 0.98, p = .34$, Cohen's $d = 0.17$, and increased it from 13.3 to 14.4 s in the control group, $t(17) = 0.99, p = .33, d = 0.20$. These differences are small and nonsignificant. Articulatory suppression was slightly more detrimental to secondary task performance for the SLI group, $t(17) = 2.69, p = .02, d = 0.68$, than for the control group, $t(17) = 1.14, p = .27, d = 0.41$. In sum, there was no evidence that the performance of children with SLI was less susceptible to articulatory suppression than was that of the controls.

Table 4.3***Dual Task Results***

	SLI (<i>n</i> = 18)	Controls (<i>n</i> = 18)
ToL accuracy (% correct)		
AS	42.9 (27.3)	50.0 (16.8)
Foot-tapping	52.4 (25.8)	62.5 (14.3)
ToL response time (s)		
AS	14.2 (6.5)	14.0 (5.6)
Foot-tapping	15.3 (6.4)	13.1 (3.2)
Secondary task errors (% of trials)		
AS	32.6 (30.5)	17.3 (18.7)
Foot-tapping	15.3 (19.0)	10.1 (16.6)

Note. All figures are *M* (*SD*). AS = articulatory suppression; ToL = Tower of London. Secondary tasks are AS and foot-tapping.

4.5 Discussion

Our aim was to test two hypotheses: (a) that the development of self-directed speech would be delayed in SLI, and (b) that the development of self-directed speech would be disturbed by early language difficulties, resulting in its relative absence or reduced effectiveness in middle childhood in SLI. The private speech of children with SLI was less internalised than that of the controls on both the ToL and a digit span task, but the groups did not differ in the susceptibility of ToL performance to articulatory suppression. The results therefore suggest that the development of self-directed speech is delayed but not deviant in SLI.

The results indicate that delay in the development of self-directed speech might explain the poor performance of children with SLI on some nonlinguistic

tasks. Although the impaired ToL performance of the SLI group could not be explained in terms of self-directed speech in the present study, as indicated by the dual task results, the performance of children with SLI might suffer on tasks requiring more complex language. A related point is that, in middle childhood, immaturity in self-directed speech development manifests itself as a lesser degree of internalisation, but, in early childhood, it presumably manifests as a delay in the emergence of private speech. At a younger age we would therefore expect the rate of private speech to be lower among children with SLI than among their typically developing peers, and for this to contribute to impaired performance on any task that is amenable to speech in typically developing children. We recommend that future studies of nonlinguistic abilities in SLI include measures to assess the extent to which delayed self-directed speech development contributes to any impairment found.

Clinical implications are that it may be helpful to encourage the development of private speech in young children with SLI to attempt to mitigate the knock-on effect that language impairment might have on nonverbal cognition. Simply modelling private speech is ineffective (see Diaz & Berk, 1995), but mature private speech production can be fostered in joint activity by initially working collaboratively and then relinquishing control of a task as the child becomes more competent (Diaz et al., 1992; Winsler et al., 1999). We see little value in attempting to speed the internalisation of private speech, and would imagine it to be a difficult and perhaps even counterproductive endeavour. However, for academic examinations and other assessments where silence is usually expected, children who rely on overt speech may benefit from being tested in an environment where speaking is permitted.

Although we have interpreted the group difference in internalisation scores as representing a delay in the overall development of self-directed speech, two other interpretations are possible. One is that the children with SLI, who were presumably accustomed to working with speech and language therapists and teaching assistants, felt less inhibited in their speech production than did the typically developing controls, for whom working one-to-one with an adult is most likely a rarer event. The fact that social speech was infrequent in both groups speaks against this possibility, but we note that social speech was more frequent in the SLI group than among the controls. Future research could investigate whether the group difference in internalisation scores generalises to the private speech produced in a nonsocial setting.

The other alternative interpretation of the internalisation results is that they represent not a delay in the overall development of self-directed speech, entailing an earlier delay in the emergence of private speech, but a delay specifically in the internalisation of private speech to form inner speech. The implication of Vygotsky's (1934/1987) work is that speech is internalised as the verbal self-regulation system becomes more efficient, so if speech is (for some tasks) less effective for children with SLI than for their peers, their private speech might remain external for longer. Other authors cite social pressure not to speak to oneself as the major cause of internalisation (Duncan & Tarulli, 2009), something children with SLI might experience to a lesser degree than typically developing children. These are two reasons to suspect that there would be a delay in internalisation, either in addition to or instead of a delay in the emergence of private speech.

As the self-directed speech of the SLI group appeared to be as effective as that of the control group, as indexed by the susceptibility of ToL performance to

articulatory suppression, the group difference in ToL performance is left unexplained. The SLI group's poorer performance is consistent, however, with previous reports of impaired visual-spatial short-term memory in SLI (e.g., Bavin et al., 2005) and possibly supports views of SLI as arising from deficits in general processing (see Leonard, 2000).

The present study had two significant limitations. First, it was cross-sectional in design, and the results apply only to middle childhood, so some of the possible implications should be treated with caution. Second, there were only two measures of the participants' language abilities; future research could include more measures to see if any particular profile of language impairment is associated with delayed development of self-directed speech. In particular, it might be fruitful to see if expressive or receptive impairment is particularly damaging to self-directed speech development, and to examine the contribution of pragmatic as well as syntactic impairment. Finally, future studies could include a measure of ADHD symptomology, to test for associations between self-directed speech variables and self-regulation among children with SLI.

In the meantime, the findings of the present study on the internalisation level of private speech were clear and consistent across tasks, and we imagine they will be useful for those wishing to understand the nonlinguistic impairments found in SLI, and for the speech and language therapists and teachers who work with this population. More broadly, the findings add to a growing body of research suggesting that theories of cognitive development should take into account cognitive benefits associated with development in the online use of language for thinking.

Footnotes

¹The frequency of participants' private speech production has, in previous research on autism, been taken as a measure of the extent to which their cognition is verbally mediated, with more private speech indicating more typical development (Winsler, Abar, Feder, Schunn, & Rubio, 2007). However, in middle childhood, more frequent private speech production could be viewed as a sign of immaturity in self-directed speech development, as children should by then be on a downward slope of private speech production, as it is internalised to form inner speech (Fernyhough & Meins, 2009). Given these conflicting perspectives, the frequency of private speech production was measured but was not considered informative with respect to the hypotheses.

²A language-matched control group was not included, in line with other studies of the effects of language impairment on cognition and self-regulation (Akshoomoff et al., 2006; Bavin et al., 2005; Bishop & Norbury, 2005a,b; Farrant et al., 2006; Fujiki et al., 2002; Im-Bolter et al., 2006; Mainela-Arnold et al., 2006; Weckerly et al., 2001; Windsor et al., 2008). We determined that the addition of another control group would add nothing to the interpretation since the comparison with an age- and nonverbal-IQ-matched control group would allow us to test for the presence of both delay and deviance in self-directed speech development.

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**Is the Development of Self-Directed Speech
Domain-General? The Psychometric Properties
of Private Speech Production**

This chapter comprises the following manuscript: Lidstone, J. S. M., Meins, E., & Fernyhough, C. (2010). *Cross-task consistency, longitudinal stability, and cross-context consistency of individual differences in private speech production in middle childhood*. Manuscript submitted for publication.

5.1 Abstract

Children often talk themselves through their activities: They produce private speech (PS), which is internalised to form inner speech (silent verbal thought). Children's PS has been the subject of much research, but little is known about its psychometric properties—the consistency of individual differences in PS production across tasks, across timepoints, and across contexts. In the present study, twenty-five 8- to 10-year-olds completed four tasks in a laboratory context (Tower of London, digit span, and two measures of spatial IQ). PS production was recorded. Eleven months later, the same participants completed the Tower of London and academic numeracy tasks, again in a laboratory context, and they completed numeracy tasks in a naturalistic classroom context. Rates of PS production and its level of internalisation showed large positive correlations over the 11 month period, across tasks, and across contexts. The results are interpreted in terms of the psychometric properties of PS production, and are taken as evidence for the development of a domain-general system for the verbal mediation of cognition in childhood.

5.2 Introduction

Private speech (PS) is the self-directed speech that emerges during the preschool years, when children start to talk themselves through their activities. It appears to be functionally related to cognitive performance: Not only does it appear at times of difficulty with a task (Behrend, Rosengren, & Perlmutter, 1989; Duncan & Pratt, 1997; Kohlberg, Yaeger, & Hjertholm, 1968; Fernyhough & Fradley, 2005), but its production is associated with success on a variety of tasks (Behrend, Rosengren, & Perlmutter, 1992; Bivens & Berk, 1990; Fernyhough & Fradley, 2005; Winsler, Diaz, & Montero, 1997). The incidence of fully overt PS drops off during early childhood, and in middle childhood, PS is more likely to take the form of covert muttering and whispering, and silent, verbal lip movements (Kohlberg et al., 1968; see also Winsler, 2009). It is thought that this shift towards covert PS reflects the gradual internalisation of PS to form inner speech, or verbal thought (Vygotsky, 1934/1987). As such, covert PS is considered to be more mature than fully overt PS. In the most widely used scheme for categorising PS (Berk, 1986), the least mature type of PS is task-irrelevant PS (Level 1), followed by task-relevant overt PS (Level 2), then partially internalised PS (Level 3).

5.2.1 *A domain-general shift to verbal mediation*

Vygotsky interpreted the emergence of PS as marking a radical reorganisation of children's cognition: "The most significant moment in the course of intellectual development, which gives birth to the purely human forms of practical activity and abstract intelligence, occurs when speech and practical activity converge" (Vygotsky, 1930-1935/1978, p. 24). He compares this transformation to

that which occurs in practical activity with the addition of tools. That cognition becomes subject to the organising function of language, he argues, will be apparent in the domains of perception, attention, “thinking,” and “active remembering”—in sum, most goal-directed thinking. The claim was thus not merely that some activities become amenable to verbally-mediated strategies but rather that, by middle childhood, goal-directed cognition is fundamentally verbal in nature. In today’s terms we would say that Vygotsky predicted *domain-general* development of verbal mediation (Al-Namlah, Fernyhough, & Meins, 2006). Children’s production of PS has been documented in the context of a wide range of cognitive tasks, including problem-solving tasks (Behrend et al., 1992; Berk & Spuhl, 1995; Daugherty, White, & Manning, 1994; Winsler, de León, Wallace, Carlton, & Willson-Quayle, 2003; Winsler, Diaz, McCarthy, Atencio, & Adams Chabay, 1999), executive function tasks (Fernyhough & Fradley, 2005; Müller, Zelazo, Hood, Leone, & Rohrer, 2004; Winsler, Abar, Feder, Schunn, & Rubio, 2007; Winsler, Diaz, Atencio, McCarthy, & Adams Chabay, 2000; Winsler et al., 1997; Winsler & Naglieri, 2003; Winsler, Naglieri, & Manfra, 2006), and schoolwork in both language (Berk & Landau, 1993) and mathematics (Berk, 1986; Berk & Landau, 1993; Berk & Potts, 1991; Bivens & Berk, 1990; Ostad & Sorensen, 2007). That PS is useful for such a broad range of tasks supports neoVygotskian ideas about the domain-generality of verbal mediation.

However, better evidence pertaining to this stance on domain-generality would perhaps come from an analysis of whether or not individual differences in children’s PS production are stable across different types of task. Cross-task correlations would imply that PS represents “not just moment-to-moment articulation of ongoing thought processes during task-specific problem solving, but

instead a coherent set of verbal self-regulatory strategies that have developed over time into an organized way of guiding one's behavior" (Winsler, 2009, p. 8).

Cross-task correlations in PS production have, to our knowledge, been reported in only one published study. Winsler et al. (2003) investigated the consistency of individual differences in 32 preschoolers' PS production across two tasks. The first was a selective attention task; for each trial the participants viewed two pictures and indicated, by choosing a third picture, what attribute the other two pictures shared. For the second task, participants attempted to reproduce a Lego structure according to an accessible three-dimensional model previously constructed in collaboration with the experimenter. The authors reported a large cross-sectional correlation between the two tasks in terms of the total rate of PS production (Pearson's $r = .70$). The proportion of the PS that was of each developmental level showed less evidence of cross-context consistency: The cross-task correlations for Levels 1, 2 and 3 were .02, .33, and .62 respectively. Only the last of these was statistically significant. There was therefore evidence of good cross-task consistency in the rate of PS production, but less evidence of cross-task consistency in its internalisation level.

Therefore there is some evidence of domain-generalty of PS, but it is somewhat limited at present. One domain that has been somewhat neglected in PS research is that of short-term memory. Some memory tasks such as remembering words and digits are by definition verbally mediated; however, very little is known about children's PS production during such tasks. On the basis of the extant literature, our knowledge is limited to the observation that young children seem to produce PS when presented with speech-based information (e.g., colour names) to remember (Patrick & Abravanel, 2000; Winsler, Manfra, & Diaz, 2007). Whether or

not this is related to the production of PS during other tasks (e.g., mathematics or executive function) is not known.

5.2.2 Psychometric properties of private speech production

The cross-task consistency of PS production takes on added importance when considered in relation to methodological concerns. In many types of PS research, a single measurement of children's PS production is taken as representative of their PS production in general. This is particularly the case in (a) research examining the *developmental significance* of PS production (correlating PS production with individual differences in outcome measures of self-regulation, theory of mind, etc.), and (b) research comparing the PS production of children with *developmental disorders* to that of typically developing children. In these two endeavours, researchers assume that, had PS production been measured on a slightly different task, individual differences in its rate and level of internalisation would not have been substantially different (Winsler, 2009; Winsler et al., 2003). Similarly, it is assumed that measuring PS production at a different time, or in a context other than the laboratory, would not have resulted in very different findings. These important issues relating to the psychometric properties of PS production have been largely neglected to date. To our knowledge there are only two relevant published studies: Winsler et al.'s (2003) study described above, which also addressed the longitudinal stability of PS production, and a study by Berk and Landau (1993), which looked at cross-context consistency.

Winsler et al. (2003) addressed the longitudinal stability of PS by having their preschool-aged participants complete the selective attention and Lego construction tasks on a second occasion, 6 months after the first session. They found

that individual differences in the total rate of PS stayed constant over the 6 month test-retest period ($r = .35$), although the correlation was smaller than the cross-task correlation mentioned above. The correlations for the *proportion* of PS that was of Levels 1, 2 and 3 were .07, .39, and .28 respectively. Only the largest of these was statistically significant. There is therefore some (somewhat equivocal) support for the longitudinal stability of PS production.

Although a degree of longitudinal stability is to be hoped for, in the sense that we would like to see test-retest reliability in PS measurements, we should also expect to see some individual differences in the rate of development. That is, the proportion of PS that is partially internalised might increase more quickly for some children than others. We imagine that this would be particularly true in early childhood, when the rate of change in PS production is very great. In middle childhood, when the shift to verbal mediation has been accomplished, we might expect to see greater longitudinal stability of PS production in terms both of group means and individual differences.

The only evidence relating to the consistency of PS production across contexts comes from a study of 14 normally achieving children and 14 learning disabled children, all 9 to 12 years old (Berk & Landau, 1993). They were observed while engaged in academic (“language and math”) tasks in the classroom and in the laboratory. The authors report a significant positive cross-context correlation ($r = .58$) for the rate of Level 3 PS production. PS of Levels 1 and 2 was not reported in this part of the study as it was relatively rare, so it is difficult to tell whether or not individual differences in both the overall rate of PS production and its maturity remained consistent across contexts.

Berk and Landau (1993) also asked if a change in both context and task type would interact with and therefore appear to disrupt individual differences in PS production. Specifically, they tested whether PS production as measured in the laboratory context with a “puzzle task”—the type of task typically used in PS studies—would generalise to academic tasks completed in the classroom. Their puzzle task was the Object Assembly test from the Wechsler Intelligence Scale for Children. The rates of Level 2 and Level 3 PS production in the two different contexts were unrelated. Another finding of interest was that the production of all three levels of PS was severely reduced during Object Assembly in the laboratory compared to academic tasks completed in the classroom. The results were taken to suggest that PS production is context-specific. However, given the restricted range of PS rates in the laboratory task, the lack of correlation is not surprising, and we hypothesised that there might be consistency in individual differences in PS production across tasks *and* contexts, given sufficient interindividual variation.

In sum, there is very little evidence on the psychometric properties of PS, and what exists is somewhat inconclusive. Given the importance of these questions for both theory and methodology in this area, the principal aim of the present study was to provide further evidence pertaining to the cross-task consistency, longitudinal stability, and cross-context consistency of PS production, in a sample of typically developing children.

5.2.3 Hypotheses and design

To assess cross-task consistency, there were four tasks at one timepoint and two tasks at a second. The tasks were chosen to draw on a range of different cognitive functions, providing a test of the domain-generalty of PS production.

Hypothesis 1 was that individual differences in the rate and internalisation level of PS would show consistency across tasks (within timepoints).

The issue of longitudinal stability was investigated in relation to the PS produced during completion of the Tower of London at Times 1 and 2. The two timepoints were separated by a period of 11 months. *Hypothesis 2* was that individual differences in the rate and internalisation level of PS would remain stable over the 11-month period.

Our investigation of cross-context consistency was based on that of Berk and Landau (1993). We predicted cross-context consistency of individual differences in PS production during numeracy (mathematics) schoolwork completed in the laboratory context and numeracy schoolwork completed in the classroom (*Hypothesis 3*). Anticipating that, as in Berk and Landau's study, nearly all of the PS would fall into the "partially internalised" category, we developed a more fine-grained scale to measure the internalisation level of PS. This allowed the rate and the internalisation level of PS to be assessed separately.

We also investigated Berk and Landau's (1993) question of whether a change in both task and context would see individual differences in PS production preserved. Berk and Landau's design was modified by replacing the Object Assembly task, which is designed to be nonverbal, with the Tower of London, the performance of which is known to be verbally mediated in childhood and to produce large variation in PS production (Al-Namlah et al., 2006; Fernyhough & Fradley, 2005). We predicted that individual differences in PS production would show consistency when both the task and the context were changed, as evidenced by correlations between the PS produced during Tower of London performance in the laboratory context and that produced during numeracy work (*Hypothesis 4*).

Given the verbally-mediated nature of the Tower of London task, we did not expect to replicate Berk and Landau's (1993) finding of a severe reduction of PS in the laboratory puzzle task in comparison to the classroom schoolwork, predicting instead roughly equal levels of PS (*Hypothesis 5*).

The final hypothesis related to the mean rates and internalisation levels of PS production in the laboratory context compared to PS production in the classroom, on the same task (numeracy). Berk and Landau (1993) found that rates of overt PS were slightly reduced during schoolwork in the laboratory compared to schoolwork in the classroom (Level 1 PS observed in 0.1% and 1.3% of observation periods respectively; Level 2 PS observed in 4.7% and 5.1% of observation periods respectively). As PS rates were not measured independently of level of internalisation in Berk and Landau's study, it is unclear whether these differences reflected schoolwork in the laboratory yielding lower PS rates, greater internalisation levels, or both, compared to schoolwork in the classroom. In addition, as the cross-context differences were very small, the question of whether or not they would be replicated remained open. In line with the other hypotheses (that PS production is not context-specific), *Hypothesis 6* stated that there would be no effect of context on mean rates of PS production or mean internalisation levels. By testing Hypotheses 5 and 6 we sought to provide more evidence on whether or not PS production is "context-specific," as Berk and Landau suggest.

5.3 Method

5.3.1 *Participants*

The participants were typically developing 8- to 10-year-olds, recruited from three mainstream state schools in the North-East of England. The Time 1 procedure was part of two other studies on the verbal mediation of Tower of London performance. Thirty children took part in the procedure at Time 1. At Time 2, two had moved away from the area and three declined to participate in the present study. There were therefore 25 participants in the present study (12 boys, 13 girls). At Time 1, the mean age was 9 years; 4 months (*SD* 10 months, range 8;0 to 10;9). Time 2 occurred a mean of 11 months later (*SD* 1 month, range 9 to 12 months). Informed written consent was obtained from parents of all participating children.

5.3.2 *Design*

At Time 1, participants completed 8 Tower of London problems, a digit span task, and two subtests of the British Ability Scales: Recall of Designs, and Pattern Construction (Elliott, Smith, & McCullough, 1996). The tasks were completed in this fixed order in two sessions conducted within about two weeks of each other. At Time 2, participants completed 12 Tower of London problems, and 20 minutes' worth of whatever numeracy schoolwork was scheduled for the day of data collection. The tasks were not completed in a fixed order at Time 2, but they were completed within a period of two weeks. All tasks were completed in the laboratory context (see Section 5.3.4 for details), except for half of the numeracy work, which was completed in the classroom. See Table 5.1 for an overview.

Table 5.1*Number of Observation Periods for Each Task*

Task	Mean	SD	Range
Time 1 Tower of London	8	0	-
Digit span	9	2	6 – 12
Recall of Designs	10	2	6 – 12
Pattern Construction	13	2	9 – 16
Time 2 Tower of London	20	6	12 – 39
Numeracy: laboratory context	66	25	21 – 127
Numeracy: classroom	60	24	16 – 114

Note. All tasks were completed in a laboratory context, apart from one of the numeracy sessions, which was completed in the classroom. At Time 1, an observation period was a trial. At Time 2, an observation period was 10 seconds of on-task time.

5.3.3 Tasks**5.3.3.1 Tower of London (Time 1 and Time 2)**

Participants performed the three-disk Tower of London (Shallice, 1982), completing eight 2- to 5-move problems at Time 1 and twelve 3- to 5-move problems at Time 2. The problem set was more difficult at Time 2 because of the

children's increased proficiency at Time 2 compared to Time 1. Each of the 20 problems was structurally unique. We used a modified Tower of London procedure, adapted from Owen et al. (1995), designed to encourage the participants to plan their moves in advance. For each problem, participants viewed the start and end states, and responded by telling the experimenter the minimum number of moves required to make the states match. Participants were then asked to demonstrate the moves they had planned. Only the period between the start of the trial and the verbal response, the planning phase, was coded for PS.

5.3.3.2 Digit span (Time 1)

Participants completed the digit span task once in each of two conditions as part of a dual task paradigm for another study. In one condition they tapped their foot while doing the task. In the other they repeated the word *Monday* instead of foot-tapping. The order of the conditions was counterbalanced. Only the results from the tapping condition are used in the present study. The digit span task was based on that of Chincotta and Chincotta (1996). For each trial, participants were presented, on a laptop computer screen, with digits at a rate of one per second. After the last digit, there was a blank screen for 4 seconds, and then a question mark appeared. Upon seeing the question mark, participants were required to orally recall the digits in the order in which they had been presented. Only the period between the start of the trial and the presentation of the question mark was coded for PS. The trials were organised in blocks of three sequences of the same length, starting with sequences of two digits. Participants proceeded to the next level if and when they had recalled two sequences of the current length correctly.

5.3.3.3 Recall of Designs (Time 1)

For each trial, participants viewed an abstract line drawing for 5 seconds and then attempted to reproduce it from memory on squared paper. Participants started at trial 1 or 3 depending on their age (as per the guidelines), and continued until trial 14 or until they scored 0 on five consecutive trials—whichever came first.

5.3.3.4. Pattern Construction (Time 1)

For each trial, participants were required to put together between 2 and 9 cubes to create a larger two-dimensional pattern to match a picture, which remained in view until the end of the trial. Each block had four different sides of all yellow, all black, or a combination. Participants started at trial 8 and continued to trial 20 or until they failed to create the required pattern within the time limit on 5 consecutive trials, whichever came first. The period coded for PS ended either when the participant indicated they had finished or when the time limit was reached—whichever came first.

5.3.3.5 Numeracy (Time 2)

Participants engaged in whatever numeracy work was scheduled for that day at school. The teacher typically introduced the lesson and then tutored the whole class on the topic. Then class members were required to individually practise the skills learned. Tasks included practising written methods of addition, subtraction, multiplication and division; deducing, measuring and drawing angles; and drawing and interpreting tables and graphs. Half of this work was done by participants in the classroom as normal, and the other half was completed in the laboratory context.

5.3.4 Observation

The laboratory context in the present study was an analogue created at the participants' schools. We saw the key features of the laboratory context as comprising (a) unfamiliarity of the testing environment, and (b) the social context of task completion—working individually rather than in parallel with others, in the presence of a relatively unfamiliar experimenter. To recreate the unfamiliarity of the laboratory context, we worked in rooms of the schools that the children were not normally permitted to enter, being reserved for staff only. The participants completed the tasks individually with the experimenter nearby, providing general encouragement at intervals. A camcorder recorded the participants' PS.

In the classroom, a webcam was used as it was smaller than the camcorder and could be securely attached to participants' desks. Participants were aware they were being filmed at all times but otherwise worked in a normal classroom setting. This differed from the laboratory context in that the physical environment was very familiar to the participants; they worked in parallel with (and within earshot of) their peers, and there was no immediate adult presence. The participants did not appear to find the camera distracting or inhibiting in either context.

5.3.5 Coding

PS was coded from the video recordings. On the basis of Berk and Landau's (1993) results, we anticipated that production of task-irrelevant PS would be negligible, so PS was defined as speech, including muttering, whispering, and silent verbal lip movements, that was relevant to the task, and not directed towards the experimenter (in the laboratory context) or peers or teachers (in the classroom).

The rate of PS production was quantified as the percentage of observation periods that contained PS. At Time 1, an observation period was simply a trial. A trial-by-trial analysis was not possible for the numeracy work, so at Time 2 an observation period was defined as a period of on-task time lasting 10 seconds, after Berk and Landau (1993). Berk and Landau employed live observation, so, of every 30 seconds, the first 10 were spent observing, and the next 20 were spent writing the PS codes on record sheets. As we had video recordings that could be paused, we had three 10-second observation periods in every 30 seconds of on-task time. Similarly to Berk and Landau, off-task time in the present study included (a) time spent watching, listening to, or interacting with peers and teachers and, in the laboratory context, the experimenter, and (b) during numeracy work, time spent sharpening pencils, finding erasers, etc. The mean number of observation periods for each task is shown in Table 5.1.

Where PS was present during an observation period, it was coded in terms of its level of internalisation. As described above, task-relevant PS has traditionally been coded simply as either overt (fully externalised PS) or covert (external manifestations of inner speech, including inaudible muttering, and silent, verbal lip and tongue movements; Berk, 1986). We developed a more fine-grained scale of internalisation level based on these categories. We considered two dimensions of covertness: intelligibility (two levels: intelligible and unintelligible) and audibility (four levels: silent lip movements, whispering, muttering, and normal speaking). Combining these dimensions created the following five categories of internalisation:

- 1 Silent verbal lip movements OR Unintelligible and barely audible whispering
- 2 Audible unintelligible whispering OR Intelligible barely audible whispering
- 3 Intelligible whispering OR Unintelligible muttering
- 4 Intelligible muttering
- 5 Normal speaking

Each observation period with PS was given an internalisation score. The internalisation score of an observation period was the mean of all the utterances in that observation period. For example, a period containing two level 2 utterances and one level 3 utterance scored $(2 + 2 + 3) / 3 = 2.33$. A participant's internalisation score for the task was the mean score of all the observation periods with PS. The range of possible internalisation scores was thus 1.0 to 5.0, with lower scores indicating more internalised PS.

The internalisation level of PS was not coded for the Recall of Designs and Pattern Construction as PS was produced by less than 20% of the sample. Therefore only rates of PS production are reported for these two tasks. The sound quality of three of the recordings of numeracy work in the classroom was not sufficient to allow coding of internalisation levels, but the coding of PS rates was unaffected.

A second researcher independently coded 20% of the recordings, five for each task, to allow the assessment of inter-rater reliability. For the presence/absence of PS during an observation period, the coefficient of agreement (Cohen's κ) was .86. For internalisation scores, inter-rater reliability (intraclass correlation) was .88. Evidence of the internalisation scale's validity as a measure of the maturity of PS comes from the fact that there were negative correlations between internalisation scores and age for all tasks (see below).

5.4 Results

The distribution of 9 of the 12 PS variables differed from normal (Shapiro-Wilk tests, $p < .05$), so all statistical tests are nonparametric. Correlations are Spearman's rank correlation coefficient (ρ). Related samples are compared with the Wilcoxon signed-rank test (Z). Independent samples are compared with the Mann-Whitney U test. All tests are two-tailed.

Mean PS rates were between 18.7% and 63.0% on the various tasks (Table 5.2). The range of PS rates was large for all tasks.

The rate of PS on the Tower of London was higher at Time 2 than at Time 1, $Z = 2.38$, $p < .05$ (a result which remained the same when the PS rates at both timepoints were calculated on the basis of 10-second observation periods), but cross-sectional correlations between age and PS production on the Tower of London were small and nonsignificant, $\rho(25) = -.03$, ns , at Time 1, and $\rho(25) = -.10$, ns , at Time 2.

The mean internalisation scores at Time 1 were very low, equating to the observation of almost exclusively silent verbal lip movements and/or unintelligible and barely audible whispering—a high level of internalisation. The numbers of participants gaining a score other than 1.0 on the Tower of London and the digit span task at Time 1 were 6 and 4 respectively, so there was insufficient variation in these variables for correlation analyses. Therefore only Time 2 internalisation scores were used to determine cross-task consistency of the internalisation level of PS.

PS on the Tower of London trials at Time 1 was more internalised than that produced during the Tower of London trials at Time 2, $Z = 2.31$, $p < .05$ (the latter of which were more challenging). Cross-sectional correlations between internalisation scores and age were, however, negative: for the Tower of London at Time 2, $\rho(21) =$

-.39, $p = .08$; for numeracy in the laboratory context, $\rho(24) = -.40$, $p = .05$; for numeracy in the classroom, $\rho(22) = -.29$, *ns*.

Correlations between all PS variables are shown in Table 5.3.

Table 5.2

Mean Private Speech Rates and Internalisation Scores for Each Task

Time	Task	Private speech rate ^a			Internalisation scores			
		Mean	<i>SD</i>	Range	<i>N</i>	Mean	<i>SD</i>	Range
1	Tower of London	38.5	31.4	0.0 – 100.0	19	1.2	0.5	1.0 – 2.3
	Digit Span	50.8	32.5	0.0 – 100.0	21	1.1	0.4	1.0 – 2.5
	Recall of Designs	19.6	32.4	0.0 – 100.0	-	-	-	-
	Pattern Construction	18.7	29.3	0.0 – 94.0	-	-	-	-
2	Tower of London	63.0	39.0	0.0 – 100.0	21	1.7	0.9	1.0 – 3.6
	Numeracy: laboratory context	45.0	35.3	0.0 – 100.0	24	2.1	1.0	1.0 – 3.8
	Numeracy: classroom	48.4	23.5	12.1 – 97.6	22	2.8	1.0	1.2 – 4.5

Note. $N = 25$ unless otherwise shown.

^aPercentage of observation periods with private speech.

Table 5.3***Correlations Among Private Speech Rates and Internalisation Scores***

		Time 1		Time 2				
		ToL	DS	RD	PC	ToL	Num (lab)	Num (class)
T1	Tower of London	-	-	-	-	-	-	-
	Digit span	.59** .16 _a	-	-	-	-	-	-
	Recall of Designs	.71***	.55**	-	-	-	-	-
	Pattern Construction	.64**	.47*	.65***	-	-	-	-
T2	Tower of London	.54** .57_b*	.63** .50 _a *	.54**	.51**	-	-	-
	Numeracy: laboratory context	.25 .25 _c	.39 [†] .04 _d	.22	.10	.51* .47_b*	-	-
	Numeracy: classroom	-.01 .27 _a	.19 -.01 _e	.09	.09	.38[†] .24_d	.53** .58_f**	-

Note. Abbreviations in the second row correspond to the tasks shown in the second column. Each cell contains a correlation coefficient pertaining to the relation between rates of PS production. Where there are two correlation coefficients in a cell, the second refers to internalisation scores. Coefficients in bold are those that relate to the hypotheses. $N = 25$ for all analyses except where subscripts indicate otherwise: ^a $n = 17$, ^b $n = 21$, ^c $n = 18$, ^d $n = 20$, ^e $n = 19$, ^f $n = 22$.
[†] $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$.

5.4.1 Hypothesis 1: Individual differences in PS production are consistent across tasks

With regard to the consistency of PS rate rankings across tasks, there were large positive correlations among all Time 1 variables (ρ s between .47 and .71), and among PS rates on numeracy in the laboratory context and the Tower of London at Time 2 ($\rho = .57$). Internalisation scores at Time 2 on the Tower of London were positively correlated with those during the numeracy tasks in the laboratory context ($\rho = .47$). Without exception, then, the correlations supported the idea of cross-task consistency in PS production.

5.4.2 Hypothesis 2: Individual differences in PS production remain stable over time

PS rates showed stability over time, as there was a significant positive correlation between PS rates on the Tower of London at Time 1 and the Tower of London at Time 2 ($\rho = .54$). There were also significant correlations between PS rates on the Tower of London at Time 2 and those on all the other Time 1 tasks (ρ s between .51 and .63). Internalisation scores for the Tower of London at Time 1 correlated significantly with those at Time 2 ($\rho = .57$).

5.4.3 Hypothesis 3: Individual differences in PS production are consistent across contexts

For numeracy work, PS rates and internalisation levels were significantly and positively correlated across contexts ($\rho = .53$ and $\rho = .58$, respectively).

5.4.4 Hypothesis 4: Individual differences are consistent across both task and context

The PS produced during the Tower of London in the laboratory was compared with that produced during numeracy work in the classroom. The positive correlation between the PS rates in the two contexts approached significance, $\rho(25) = .38$, $p = .06$, and there was a positive correlation between the internalisation scores that did not reach significance in this small sample, $\rho(20) = .24$, *ns*.

5.4.5 Hypothesis 5: Private speech production during Tower of London performance in the laboratory context does not differ from private speech production during numeracy work in the classroom

The Tower of London PS was more frequent, $Z = 3.94$, $p < .001$, and more internalised, $Z = 3.17$, $p < .01$, than the PS produced during numeracy work in the classroom (Table 5.2).

5.4.6 Hypothesis 6: Private speech production during numeracy work in the laboratory context does not differ from private speech production during numeracy work in the classroom

PS rates did not vary across contexts for numeracy, $Z = 0.31$, $p = .76$, but the PS produced during numeracy work in the laboratory context was more internalised than that produced in the classroom, $Z = 2.99$, $p < .01$ (Table 5.2).

5.5 Discussion

The aim of the present study was to investigate the cross-task consistency, longitudinal stability, and cross-context consistency of individual differences in PS

production, in terms of the rate of PS production and its internalisation level. The results indicated that the rate and internalisation level of PS showed strong consistency across tasks (*Hypothesis 1*) and stability over time (*Hypothesis 2*). For the numeracy work, there was consistency across contexts in terms of individual differences in both rates and internalisation levels (*Hypothesis 3*). When both the task and the context were changed (i.e., comparing the Tower of London in the laboratory context with numeracy work in the classroom), the PS rates were positively correlated, and there was a positive correlation between the internalisation scores that did not reach statistical significance in this small sample (*Hypothesis 4*). Regarding the effect of context and task on rates and internalisation levels of PS, the Tower of London PS at Time 2 was more frequent and more internalised than the PS produced during numeracy work in the classroom (contra *Hypothesis 5*). PS rates did not vary across contexts for numeracy work, but the PS produced during numeracy work in the laboratory context was more internalised than that produced in the classroom (*Hypothesis 6*).

The findings relating to cross-task consistency in this study of PS in middle childhood thus accord with those of Winsler et al.'s (2003) study of preschoolers. The results indicate that, in studies of PS, one task can be used to gauge PS use in general in a given context at a given timepoint. That the emergence of PS and its maturity show cross-task correlations suggests that the shift to verbal mediation and its development are domain-general. The findings are of particular interest in that they are the first relating PS production on a memory task (digit span) to PS production on other tasks (but see also Al-Namlah et al., 2006). In addition, although the spatial IQ tasks yielded lower PS rates than the tasks known to be verbally mediated, PS was found during approximately 20% of the trials, and it appeared to

be meaningfully related to the PS produced during verbally-mediated tasks. The idea that some spatial or nonverbal IQ tasks are verbally mediated is supported by a dual task study finding that suppression of verbal processes during adults' performance of Raven's Matrices is deleterious to their performance (Kim, 2002).

The present study found stronger evidence of longitudinal stability over 11 months than Winsler et al. (2003) found over 6 months. While Winsler et al. found evidence of longitudinal stability of individual differences in rates of overt PS but not covert PS, we found that participants' rankings in both rates and internalisation scores were stable over time. The discrepancy between the two studies' findings might relate to the different ages of the samples. During the preschool years (the subject of Winsler et al.'s study), PS is undergoing rapid development, and there are presumably substantial individual differences in the rate of that development. In contrast, by middle childhood (the subject of the present study), most of the work of the shift to verbal mediation has been done, and we could thus expect the characteristics of PS production to be stable over a reasonably long period of time. This stability in individuals' scores might well be accompanied by stability in individual differences in this age range. The implication of this is that a measurement of PS at a single point in time might be representative of the PS produced over a period of several months in middle childhood.

The cross-context consistency of individual differences in PS rates on academic tasks replicated the findings of Berk and Landau (1993). Our more fine-grained analysis of the internalisation level of PS allowed us to conclude that individual differences remain consistent across contexts in this respect too. The results indicate that asking children of this age to do an appropriate task in a slightly "artificial" context will not disrupt individual differences in PS production.

The present study thus indicated that PS rates and internalisation levels can be representative of the PS produced at another timepoint, or of the PS produced during another task, or of the PS produced in another context. When both the context and the task were changed (*Hypothesis 4*), the correlations were smaller but still positive. Their smaller size sounds a note of caution regarding the degree to which we can neglect issues of ecological validity in PS research. The results of the present study, taken together, though, indicate remarkably good consistency across tasks and contexts, and stability over time.

Hypotheses 5 and 6 related to how the sample's rates and internalisation levels of PS changed across contexts and tasks. Although individual differences in PS production were consistent across contexts, and rates of PS were roughly equal in the two contexts, the PS produced in the laboratory context (on both the Tower of London and the numeracy work) was more internalised than in the classroom. This supports and clarifies Berk and Landau's findings of a small cross-context difference in the incidence of overt PS, but no effect of context on the incidence of covert PS. One possible reason for the effect of context on internalisation levels is that children feel more inhibited in the laboratory context, but the fact that they produced more PS during the Tower of London in the laboratory than they did in the classroom speaks against this possibility. Another possibility is that there is more background noise in a classroom than in a laboratory context so children's PS has to be more overt in the classroom to have the same effect. The fact that PS was more overt in the classroom speaks against the idea that the main factor driving internalisation is the transition to school (Duncan & Tarulli, 2009). The children in the present study appeared to use PS freely during numeracy lessons in the classroom.

The final finding relating to the hypotheses was that the Tower of London PS at Time 2 was significantly more frequent and more internalised than the PS produced during numeracy work in the classroom. The results therefore together suggest that individual differences in PS variables are preserved even when changes of task and context affect the means.

Despite the clear findings of the present study two limitations must be acknowledged. First, the sample size was small. The potentially large effect of outliers was mitigated, however, by the fact that we conducted only nonparametric tests. The other major limitation is that reliability of PS production does not guarantee reliability of PS-behaviour relations, as the behaviours in question have to be reliable as well. For example, in Berk and Landau's (1993) study, learning disabled children's production of overt PS positively predicted task-facilitating motor activity during academic seatwork in the classroom, but not while completing the puzzle task in the laboratory. This was at least partly because the incidence of motor activity was substantially reduced during the latter situation as compared to the classroom, so there was a much smaller range of individual differences to relate to PS production. This highlights the need for future studies of the correlates of PS to address the cross-task and cross-context consistency of the behaviours in question.

In the meantime, however, the present study indicates that individual differences in both the rate and internalisation level of PS production remain stable over time, and consistent across tasks and across contexts in middle childhood. We suggest that these findings constitute evidence for the development of a domain-general system for the verbal mediation of cognition in childhood.

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General Discussion

The main purpose of this chapter is to discuss some of the recurring themes of the thesis. First there is a synopsis of the work presented in the four empirical chapters.

6.1 Summary of findings

6.1.1 Role of self-directed speech in planning in typical development

Chapter 2 reported two experiments testing the Vygotskian hypothesis that, by middle childhood, speech has taken on a planning function. Two versions of the Tower of London were used in a dual task paradigm. The secondary tasks were articulatory suppression, which is assumed to block self-directed speech, and foot-tapping (the control condition). Performance of the traditional Tower of London procedure, in which participants have to move the disks one at a time in order to reach a prespecified goal state, was not vulnerable to articulatory suppression. Considering that the traditional Tower of London procedure did not elicit much planning in this instance, Experiment 2 used a modified procedure, in which participants had to plan all the moves in advance. Performance was significantly poorer in the articulatory suppression condition than in the control condition. It was argued that this constitutes better evidence that planning is verbally mediated than does the study of private speech–performance relations, as the dual task paradigm is experimental rather than observational in design. It is also more rigorous than comparing performance under articulatory suppression to performance in a control condition with no secondary task, because the tapping task in the control condition controlled for the general task demands of articulatory suppression.

Further evidence for the validity of articulatory suppression when used in conjunction with tapping was obtained by correlating individual differences in private speech production with individual differences in interference by articulatory suppression. Children who relied more heavily on private speech during problems of intermediate difficulty experienced greater interference by articulatory suppression on those problems than did their peers. The fact that this relation occurred only for problems of intermediate difficulty provided support for previous predictions (Fernyhough & Fradley, 2005) that task difficulty level moderates the efficacy of private speech. This was the first study to combine the observation of private speech with the use of articulatory suppression, a combined design which proved to be useful for the study of self-directed speech in specific language impairment in Chapter 4. Further reasons for recording private speech in addition to using the dual task paradigm, particularly when studying self-directed speech in atypical development, are described below (Section 6.2.2).

6.1.2 Self-directed speech in autism

In Chapter 3 it was argued that, if the development of self-directed speech depends on experience of verbally-mediated joint activity, there should be a self-directed speech impairment in autism. Previous studies of phonological recoding, private speech, and the effect of articulatory suppression were reviewed; the findings were mixed. Therefore it was hypothesised that there might be a moderating variable in operation. The moderating variable proposed was cognitive profile. The hypothesis was that the social impairment of autism would produce self-directed speech impairment when it is accompanied by an imbalance in verbal and nonverbal abilities which biases children away from using self-directed speech—a NV>V

profile. Whitehouse, Maybery, and Durkin's (2006) data on the effect of articulatory suppression on task-switching were reanalysed. Interference by articulatory suppression varied with cognitive profile among children with autism but not among controls. Only the group with autism and a $NV > V$ profile showed no interference by articulatory suppression, indicating a self-directed speech impairment. Interference by articulatory suppression was not predicted by verbal ability (verbal mental age) alone. Subsequent studies on the effect of articulatory suppression on cognitive performance in autism have been somewhat equivocal in their findings, and it was suggested that the consideration of moderating variables might shed light on these results.

Two aspects of the findings warrant further discussion here. First, given the severe social impairment found in autism, why was there not an impairment in self-directed speech in all participants with autism? One reason might be that the participants with autism were all high functioning. Perhaps their symptoms were mild enough such that the development of self-directed speech was possible, though perhaps delayed. Another possible explanation relates to the type of verbal mediation under study: speech for task-switching rather than speech for more complex problem-solving and self-regulation. The nature of self-directed speech for task-switching will be considered in Section 6.2.1.2. This discussion will also help us to consider why Williams and Jarrold (2010) did not replicate the moderating effect of cognitive profile found in Chapter 3. Williams and Jarrold studied phonological recoding rather than speech for task-switching, so a consideration of whether these two types of verbal mediation are significantly different will help to establish whether or not this difference in methodology could possibly explain the difference in the findings of the two studies.

6.1.3 Self-directed speech in specific language impairment

In Chapter 3, the typically developing participants with a NV>V profile did not show self-directed speech impairment, as indexed by a lack of interference by articulatory suppression. This group's mean nonverbal mental age (11 years; 9 months) was three years greater than its mean verbal mental age (8;5), which was commensurate with its mean chronological age (8;4). Therefore the nonverbal skills of these typically developing children were advanced and their verbal skills could be considered normal. In Chapter 4, we considered what happens when there is a NV>V profile reflecting, not advanced nonverbal ability, but rather, impaired verbal ability in otherwise typical development, i.e., the case of specific language impairment (SLI). The aim of the research was to distinguish between two hypotheses, which, as in Chapter 3, stemmed from the assumption that disruption to verbally-mediated joint activity is likely to impair the development of self-directed speech. The first possibility identified was that there is a delay in the development of self-directed speech in SLI, which would show up as a lesser degree of internalisation than in controls. The second was that there is deviance in self-directed speech development in SLI, manifesting as either a tendency not to use language for cognition, or ineffective language use; both of these atypicalities would show up as a lesser degree of interference by articulatory suppression in the SLI group than in the control group. The method used was the same as that developed for Chapter 2. The private speech produced during a digit span task was also included. There was no group difference in the susceptibility of Tower of London performance to articulatory suppression, but the private speech of the SLI group was less internalised than that of the controls on both tasks. The findings suggested that children with SLI experience a significant

delay in the development of self-directed speech, but that their self-directed speech is effective for Tower of London performance in middle childhood.

If there is a delay in self-directed speech development in children with SLI, this might provide an explanation for their poor performance on some nonlinguistic tasks. Although the impaired Tower of London performance of the SLI group could not be explained in terms of self-directed speech, as indicated by the dual task results, the performance of children with SLI might suffer on tasks requiring more complex language, and the performance of younger children with SLI might suffer as a result of a delay in the emergence of private speech. In the Discussion of Chapter 4, there were suggestions for future research which would help to clarify the findings. In Section 6.2.2 below, there are suggestions for further research, the findings of which would help to refine hypotheses regarding the effect of language impairment on self-directed speech development.

6.1.4 Cross-task consistency of private speech production and other psychometric properties

In the SLI study, the private speech the two groups produced during the Tower of London and the digit span task was recorded in order to compare the groups' levels of self-directed speech development. We would hope that, in a study of this nature, the choice of tasks would not affect the results of the group comparison. That is, we would like to be able to expect *cross-task consistency* in individual differences in private speech production. The degree to which cross-task consistency can be expected in middle childhood was investigated in Chapter 5. Rates of private speech production and its level of internalisation showed large positive correlations across the four tasks completed at Time 1 and across the two

tasks completed at Time 2, 11 months later. The Tower of London was completed by participants at both timepoints and rates and internalisation levels were positively correlated longitudinally. Half the numeracy schoolwork at Time 2 was completed in the “laboratory context” as normal, and the other half was completed in the classroom, with positive correlations between contexts. Therefore both the rate and internalisation level of private speech production showed cross-task consistency, longitudinal stability, and cross-context consistency—three important psychometric properties. As the nature of the numeracy tasks differed between children, comprising whatever numeracy schoolwork was scheduled for the day of testing, the correlations involving this task are particularly impressive. They show that private speech production is robust to changes of task and to changes of context.

The cross-task correlations, particularly those between the Tower of London and digit span tasks, provide support for the notion of *domain-general* development in verbal mediation (Al-Namlah, Fernyhough, & Meins, 2006). However, cross-task correlations are not the only type of evidence that can speak to domain-generality, as will be discussed below.

6.2 Emerging issues and future directions

6.2.1 Is self-directed speech development domain general?

In this thesis the verbal mediation of several types of task has been considered. First, there was the verbal mediation of Tower of London performance and other puzzle-type tasks (such as Pattern Construction in Chapter 5). Table 6.1 shows some examples of the private speech that was observed during administration of the Tower of London for the research reported in Chapters 2, 4, and 5. The

utterances could be described as apparently aiding problem-solving and the regulation of attention and emotion. As such, this sort of speech will be described in the following discussion as *problem-solving/self-regulatory speech*. Another type of verbal mediation considered in this thesis was speech for short-term memory: the *phonological rehearsal* of material already in verbal form (digits, in Chapters 4 and 5), and memory for pictorial information that must be *phonologically recoded* before it can be rehearsed (in others' research described in Chapter 3). Finally, there was speech for task-switching in the empirical work of Chapter 3.

Table 6.1***Private Speech Utterances Produced During Tower of London Performance***

Category	Examples
Problem-solving speech	
- Counting	<i>One, two, three ...</i>
- Planning	<i>That will go there ...</i> <i>The blue one out of the way ...</i>
- Correcting	<i>No, this isn't working!</i>
Self-regulatory speech	
- Orienting to the problem	<i>Right, let's see...</i> <i>How many moves?</i>
- Coping	<i>I'll just do my best.</i>
- Externalising	<i>This is a hard one!</i>

Private speech for problem-solving/self-regulation emerges during the preschool years, whereas phonological recoding and rehearsal are generally considered, by memory researchers at least, to emerge at around the age of 7 years (Jarrold & Tam, in press). Whether or not there is a disparity here is important for two reasons. First, it relates to whether or not the shift toward verbal mediation can be considered to be *domain-general* (Chapter 5); if the shift occurs in a different manner in different domains (problem-solving/self-regulation vs. memory), this would present a significant challenge to this view, despite correlations between the development of self-directed speech in the two domains (Al-Namlah et al., 2006; research reported in Chapter 5; see Section 6.2.1.1). The second reason this is of interest is that researchers investigating inner speech in autism have tended to treat phonological recoding and problem-solving/self-regulatory speech as the same thing, potentially masking important complexities in the pattern of impairment found in autism. What follows is a comparison of the development of problem-solving/self-regulatory speech and the development of phonological rehearsal. First their potentially different ages of emergence are considered. Then there is a brief recap of the correlational evidence. Finally, their developmental origins are explored, before a discussion of where speech for task-switching fits in.

6.2.1.1 Speech for problem-solving/self-regulation and speech for memory

(a) Age of emergence

As noted above, private speech for problem-solving/self-regulation emerges during the preschool years (Berk & Spuhl, 1995; Chiu & Alexander, 2000; Duncan & Pratt, 1997; Manfra & Winsler, 2006). Private speech production during planning

in particular has been documented in children as young as 4 (Al-Namlah et al., 2006) and 5 years (Fernyhough & Fradley, 2005). There is little research of experimental design relating to the value of private speech in this age group: There are no studies of the effect of articulatory suppression on problem-solving in young children, probably due to the methodological challenges that this would present. Positive relations between private speech production and task performance (Behrend, Rosengren, & Perlmutter, 1989, 1992; Müller, Zelazo, Hood, Leone, & Rohrer, 2004; Winsler, Diaz, & Montero, 1997) are suggestive of its value in preschoolers, however. In contrast, phonological recoding and rehearsal are generally considered to emerge at around age 7. The evidence for this view is considered next. First, there is a recap of the methods used to detect phonological recoding and rehearsal.

One sign that a group of participants is engaging in phonological recoding and rehearsal is that they show a *phonological similarity effect* for pictorial information. For example, pictures depicting *cat*, *cot*, and *cup* are less well-remembered than pictures depicting *bat*, *mop*, and *cow* because the former are more vulnerable to confusion if they have been recoded into phonological form. A *word length effect* for pictorial information also indicates phonological recoding and rehearsal (Hitch, Halliday, Schaafstal, & Schraagen, 1988); that is, if phonological rehearsal is taking place, pictures depicting multisyllabic words are less well-remembered than pictures depicting monosyllabic words. This arises because phonological representations of words with a longer spoken duration in the phonological store of working memory can be refreshed less often by rehearsal.

At what point in development do these effects emerge? Jarrold and Tam (in press) catalogue a range of studies documenting a lack of a phonological similarity effect for pictures in children younger than 7 (Halliday, Hitch, Lennon, & Pettipher,

1990; Hitch, Woodin, & Baker, 1989; Palmer, 2000) and in children with developmental delay and verbal mental ages of less than 7 (Williams, Happé, & Jarrold, 2008). However, there is some evidence of phonological recoding and rehearsal before this age. Al-Namlah et al. (2006) reported a phonological similarity effect for pictorial information in a group of 4- and 5-year-olds, for example. Other research has found a word length effect for pictures in 5-year-olds (Hitch et al., 1988) and a phonological similarity effect for pictures in 5- and 6-year-olds (Tam, Jarrold, Baddeley, & Sabatos-Devito, 2010), though both of these effects were smaller in magnitude than those found in children older than 7 (Hitch et al., 1988; Tam et al., 2010). The balance of evidence therefore suggests that the shift to phonological recoding of pictorial information perhaps starts in early childhood but, in small studies, does not reliably produce a phonological similarity effect or word length effect until around the age of 7.

However, even 3-year-olds can be observed to be spontaneously labelling to-be-remembered pictures. Fifty percent of 3-year-olds evidence such a strategy according to Ford and Silber (1994). Jarrold and Tam (in press) suggest that this sort of strategy produces experimental effects, such as the phonological similarity effect and the word length effect, when it reaches a threshold of efficiency. When a strategy is used but it does not confer a benefit in task performance, this is called a *utilisation deficiency* (Bjorklund, Miller, Coyle & Slawinski, 1997; Miller & Seier, 1994), a phenomenon that has been observed in young children in relation to memory strategy development in general, if not the shift to phonological recoding in particular.

Another sign of phonological rehearsal is the word length effect for words presented aurally or orthographically. Jarrold and Tam (in press) review the evidence

and convincingly show that there is no evidence of a word length effect in under 7s (e.g., Jarrold, Baddeley, & Hewes, 2000; Turner, Henry, & Smith, 2000) despite observations in the private speech literature that 3- to 5-year-olds do overtly rehearse to-be-remembered speech-based information such as colour names (Patrick & Abravanel, 2000; Winsler, Manfra, & Diaz, 2007; but see also Flavell, Beach, & Chinsky, 1966). Again, it seems there is something of a utilisation deficiency that resolves around the age of 7. Therefore it seems that children phonologically rehearse from a young age but that it does not have a reliable effect on performance until around the age of 7.

This presents us with a hypothesis concerning problem-solving/self-regulatory speech—namely, that there would be no reliable effect of articulatory suppression on cognitive performance until around the age of 7. If confirmed, this would provide a parallel between the emergence of speech for memory and speech for problem-solving/self-regulation, and it would support the notion of a domain-general shift to verbal mediation.

What might look like a utilisation deficiency at a group level, though, might not hold at the individual level. For instance, in Ford and Silber (1994), half of the 3- to 6-year-olds overtly named pictures at presentation, but there was no phonological similarity effect at the group level. An individual differences approach like that used in Chapter 2 might reveal that children producing private speech do show a phonological similarity effect, indicating that their private speech was effective, and that the lack of phonological similarity effect in the group as a whole can be attributed to the lack of verbal mediation in the other half of the group (a *production deficiency*). A recommendation for future research is thus to combine experimental manipulations (such as the phonological similarity effect for pictorial information,

and the effect of articulatory suppression) with the study of private speech in order to look at the development of verbal mediation in both domains (problem-solving/self-regulation and phonological recoding and rehearsal) in under 7s.

To summarise so far, there is currently no strong evidence either for or against the idea that problem-solving/self-regulatory speech and phonological recoding and rehearsal develop according to different “timetables.” Nevertheless, there are other types of evidence that speak to the issue of whether or not the development of self-directed speech is domain-general. Next, we have evidence relating to whether or not individual differences in the two types of speech are correlated. Then the degree of similarity in their developmental origins will be considered.

(b) Correlations between speech for problem-solving/self-regulation and speech for memory

Al-Namlah et al. (2006) argue that, if there is a domain-general shift to verbal mediation, there should be positive relation between the degree of verbal mediation of memory and the degree of verbal mediation of problem-solving in early to middle childhood. As such, they found a correlation between the phonological similarity effect for pictures and the rate of private speech production during Tower of London performance, in their sample of 4- to 8-year-olds. Similarly, in the research with 8- to 10-year-olds reported in Chapter 5, individual differences in the amount of private speech produced on a memory task requiring phonological rehearsal (digit span) correlated with private speech produced during two problem-solving tasks, the Tower of London and the Pattern Construction subtest of the British Ability Scales. Private speech during the Pattern Construction task was relatively rare so its

internalisation level was not recorded, but the correlation between the internalisation scores of the other two tasks was large and positive. Therefore, while Al-Namlah et al. provided evidence of a domain-general shift to verbal mediation, the research presented in Chapter 5 provided evidence of the domain-generality of its continued development.

(c) Developmental origins

A third point is that we might expect the developmental origins of speech for problem-solving/self-regulation and speech for memory to be different. Recall that problem-solving/self-regulatory speech is thought to be stimulated by linguistically-mediated joint activity, and is subject to sociocultural influences (Al-Namlah et al., 2006; Berk & Garvin, 1984; see Section 1.3.1). Al-Namlah et al. (2006), who found an effect of culture on problem-solving/self-regulatory speech (in the form of a Nationality \times Gender interaction), found no such effect on the verbal mediation of memory. Although Saudi boys appeared to be somewhat disadvantaged relative to British boys in terms of the development of problem-solving speech, there was no such pattern evident in the results on the size of the phonological similarity effect for pictorial information. Indeed, Al-Namlah et al. thought a main effect of nationality possible, considering that Saudi children's education involves much more rote learning than does the education of British children: They predicted that, if self-directed speech development depends on domain-specific experience, the Saudi sample would show the larger phonological similarity effect. In fact, there was no main effect of nationality.

Is the development of speech for memory impervious to experience, then? Although there is little evidence specifically relating to phonological recoding and

rehearsal, the social context of memory development in general has long been recognised (Flavell & Wellman, 1977; Nelson & Fivush, 2000), and there is some work on the development of other memory (mnemonic) strategies. Development of mnemonic strategies is influenced by teachers, for example, as evidenced by associations between their *mnemonic orientation* (Coffman, Ornstein, McCall, & Curran, 2008) and children's use of mnemonic strategies. For instance, Moely et al. (1992) found that lower-achieving children were more likely to use organisation strategies to aid recall in an experimental task situation if their teachers frequently provided strategy suggestions for remembering. Because teaching occurred at the group level, teachers' strategy-teaching presumably was not a response to the individual children's amenability to such teaching, but rather a reflection of their own teaching style. A second important finding was that lower- and average-achieving children whose teachers provided strategy suggestions more frequently in class were more responsive to a memory training session in which memory strategies were taught by an experimenter.

Coffman et al. (2008) extended this work by providing a longitudinal perspective. They found that first grade children whose teachers were classified as high in mnemonic orientation showed more sophisticated memory strategy skills by the Spring of that school year: They used more sorting and clustering strategies during a "sort-recall" task and more mnemonic strategies during an "object memory" task than did their peers with less mnemonically oriented teachers. Therefore the development of memory strategies appears to be influenced by social experience, and although this evidence relates to different memory strategies, there is no obvious reason to suspect that the development of phonological recoding and rehearsal would be any different.

Whether or not the development of speech for memory and speech for problem-solving/self-regulation depend on the same kinds of social experience, though, is a different matter. The research on mnemonic orientation refers to teachers' explicit tutoring of memory strategies whereas problem-solving/self-regulatory speech arises more organically from linguistically-mediated joint activity and indeed seems to be resistant to explicit coaching (Diaz & Berk, 1995). To see if problem-solving/self-regulatory speech and phonological recoding and rehearsal are influenced by the same experiences, a training study might be valuable. The aim would be to see if an intervention to advance development in the use of speech for problem-solving/self-regulation would also increase the use of speech for a memory task, and vice versa. Given that development in the two domains correlates, we might expect there to be some overlap. On the other hand, the cause of the correlations might be that parents who are sensitive scaffolders are also more mnemonically oriented; if so, the actual experiences influencing development in the two domains still might be different.

(d) Summary: Speech for problem-solving/self-regulation and speech for memory

At present it is unclear whether or not the development of self-directed speech proceeds in a domain-general manner, although the correlations between domains suggest it does. More research on the early development and developmental origins of speech for problem-solving/self-regulation and speech for memory would help to clarify the extent of their similarity.

6.2.1.2 *Speech for task-switching*

The other major function of self-directed speech considered in this thesis was for task-switching (Chapter 3). If the development of speech for problem-solving/self-regulation and the development of speech for memory do turn out to be domain-specific, this would raise the question: Which type does speech for task-switching more closely resemble? Unfortunately it is not known at what age private speech for task-switching emerges, how it relates to other forms of verbal mediation, or how best to characterise its developmental origins. A theoretical analysis of its structure and function, however, reveals similarities with both speech for problem-solving/self-regulation and speech for memory. In terms of its *structure*, speech for task-switching might more closely resemble phonological recoding and rehearsal than problem-solving/self-regulatory speech, if it consists of the recitation of single words (e.g., *plus, minus, plus, minus*). The *function* of speech for task-switching has been framed in terms of helping to keep track of which task is next and in terms of activating the task-set for the upcoming task. There is evidence for both these functions (see Cragg & Nation, 2010), but the way in which these functions relate to the possible dichotomy discussed above (problem-solving/self-regulation vs. memory) is unknown, although in general terms we might say that the function of speech for task-switching is the regulation of activity, thus making it akin to self-regulatory speech.

The issue of whether speech for task-switching and speech for memory can be considered to be part of the same phenomenon is of interest in relation to the conflicting findings of the research on task-switching presented in Chapter 3 and the research of Williams and Jarrold (2010) on phonological recoding in autism. The results of Chapter 3 suggest that inner speech use varies with cognitive profile in

autism, whereas Williams and Jarrold's findings suggest that phonological recoding is normal in children with autism, emerging at the verbal mental age of 7 years. Participants with verbal mental ages of over 7 showed a phonological similarity effect for pictures, regardless of autism diagnosis, cognitive profile, and chronological age. Considering that mnemonic strategies seem to be more amenable to explicit teaching than is the development of speech for problem-solving, perhaps we should not be surprised if phonological recoding and rehearsal are completely intact in autism. Given its self-regulatory function, we would expect speech for task-switching to be more sensitive to moderating variables such as cognitive profile.

6.2.2 Self-directed speech in atypical development

If the developmental origins of speech for problem-solving/self-regulation and speech for memory are different, we might expect them not to be uniformly spared or impaired in atypical development, even if they tend to go hand-in-hand in typical development. In addition, we might expect dissociations within the problem-solving/self-regulation category: Considering that individuals with autism have problems monitoring their own mental states (Williams, 2010), we might expect speech for self-regulation to be impaired as a direct result of problems of self-awareness (see Fernyhough & Meins, 2009). Speech for problem-solving, on the other hand, would be impaired to the extent that its development relies on syntactic and pragmatic language abilities, and the experience of verbally-mediated joint problem-solving. Therefore, in future studies of self-directed speech in autism, it might be unwise to rely solely on the dual task paradigm: Recording private speech and its apparent function could also provide some valuable insights. Another reason for recording private speech is to measure its internalisation level, as in Chapter 4.

Note, though, that private speech rates cannot tell us everything we need to know. Recall that, in Chapter 4, rates of private speech were not deemed useful for comparing the extent to which two groups of children's cognition was verbally mediated. This was because there are conflicting perspectives on what private speech frequency means, especially in middle childhood. As explained in Chapter 4, the frequency of participants' private speech production can be taken as a measure of the extent to which cognition is verbally mediated, with more private speech indicating more typical development (Winsler, Abar, Feder, Schunn, & Rubio, 2007). However, in middle childhood, more frequent private speech production could be viewed as a sign of immaturity in self-directed speech development, as children should by then be on a downward slope of private speech production, as it is internalised to form inner speech (Fernyhough & Meins, 2009). Given these conflicting perspectives, the frequency of private speech production is not a useful measure of the extent to which cognition is verbally mediated, but the measurement of this can be achieved with the dual task paradigm. A recommendation for future research is to analyse both the content and the internalisation level of children's private speech in a dual task paradigm.

Thus the combination of methods—as used in Chapters 2 and 4—might prove particularly fruitful in the study of self-directed speech in atypical development. The preceding discussion illustrates that researchers should be looking at different types of self-directed speech as though they might be separate, allowing for the possibility that different types of self-directed speech are less closely associated in atypical development than in typical development.

Another point in relation to self-directed speech in atypical development is that it would be useful to have more details on exactly what aspects of joint activity

contribute to the development of problem-solving/self-regulatory private speech. NeoVygotskian theory (Fernyhough, 1996) and associated evidence (see Section 4.2) suggest that joint activity contributes to private speech development via the internalisation of *activity-related dialogue*, and this was the basis for predicting disruption to self-directed speech development in both autism and SLI. However, the extent to which adults' nonverbal behaviour during joint activity contributes to private speech development is not known. Berk and Winsler (1995) identify two nonverbal aspects of high-quality scaffolding that could be important for private speech development: (a) sensitive modulation of task difficulty and the amount of adult assistance, influencing the extent to which the task is kept at an appropriately challenging level for the child, and (b) contingent withdrawal of adult control and assistance as soon as the child is able to take on more responsibility. Winsler and colleagues (Winsler, Diaz, McCarthy, Atencio, & Adams Chabay, 1999), in their study of joint puzzle-solving activity, measured these aspects of *nonverbal scaffolding* by recording the frequency with which mothers touched the puzzle and the extent to which this decreased during the session. They found that children of mothers who withdrew control produced more partially-internalised private speech than their peers. Measures of maternal *verbal tutoring* and *verbal modelling*, on the other hand, were not related to children's private speech production. This raises the possibility that private speech production is advanced by carefully structuring the child's activity rather than by helping to create a dialogue that can be internalised. If so, we might expect little effect of receptive language impairment on private speech development in SLI, whereas the social impairments, sensory abnormalities, and restricted and repetitive behaviours found in autism, would present more of a barrier to participating in sustained well-structured activity. To summarise, the relative

importance of caregivers' verbal and nonverbal behaviour for self-directed speech development will shape our predictions regarding patterns of self-directed speech development in atypically developing children. We would expect expressive language impairment to have an effect on the online use of language regardless of whether it is caregivers' verbal or nonverbal behaviour that proves to be more important.

For the discovery of the crucial element of joint activity for self-directed speech development, again, a training study might be useful. An experimenter could investigate the effects of verbal and nonverbal scaffolding (compared to a control condition) on typically developing children's subsequent private speech production during a task. This would be an important step in gaining an understanding of how private speech emerges from joint activity, and would allow us to formulate more specific hypotheses with regard to self-directed speech development in SLI and autism.

6.2.3 Methodological innovation

One methodological contribution of the present thesis was the novel way in which the difficulty level of the tasks was controlled while comparing two groups' private speech internalisation levels in Chapter 4 (see Section 4.3.4). A second innovation was the scale measuring internalisation level used in Chapters 4 and 5 (see Section 4.3.3). The scoring of private speech using this scale showed high inter-rater reliability in both studies, and there were negative correlations between these internalisation scores and chronological age (see Section 5.4), which speaks to the validity of the scale.

With regard to future work to validate the internalisation scale, researchers could see if it shows private speech becoming more internalised with age in a longitudinal design. The challenge here would be to keep the difficulty level of the task constant, taking into account increasing proficiency as a function of cognitive development. The system of controlling for difficulty level used in Chapter 4 might be useful in this respect. The comparison of internalisation scores at different timepoints was theoretically possible in Chapter 5, but there was a confounding factor relating to the fact that the tasks were completed in the presence of an experimenter. If the participants were more socially confident at Time 2 than at Time 1, which seems likely given that nearly a year had passed, this might have had an “externalising” effect on their private speech. Computer administration of tasks would solve this problem (although, if private speech is parasocial, see Section 1.3.2, the absence of another person might markedly depress the frequency of private speech production, particularly in younger children). In future work, researchers could also see if the scale shows private speech becoming more internalised with increasing proficiency at a task on a microdevelopmental timescale.

A challenge for future work is to decide where task-irrelevant speech fits in: Can it be regarded as simply less-internalised speech than the most-overt task-relevant speech (as per Berk, 1986), and if so, how should task-irrelevant speech be incorporated into the new scale? If it should and can be incorporated, this would allow the new, more sensitive scale to be used in studies of younger children, where there is usually a significant amount of task-irrelevant private speech. The new scale could be used in some studies of younger children in its current form, however—where private speech is to be recorded in situations where there is no fixed task, such as during free play.

As already discussed, one of the main methodological contributions of the work in this thesis is the introduction of the combined private speech–articulatory suppression methodology and, over the preceding discussion, its value has become clear. The main advantage of the dual task paradigm is that it is experimental in design, allowing us to say something about self-directed speech in terms of its causal influence on cognition. The articulatory suppression–tapping combination appears to be valid, as evidenced by their equal effects on nonverbal primary tasks (Emerson & Miyake, 2003). Nevertheless, concerns about the general cognitive load of articulatory suppression are sometimes raised. Chapter 2’s finding of a positive association between private speech production and articulatory suppression interference might help to ameliorate such concerns, but, nevertheless, researchers might wish to look into other ways of suppressing self-directed speech. One avenue is possibly the use of the *irrelevant speech effect*, the phenomenon whereby participants’ phonological loop function is suppressed when they hear irrelevant speech; this is not simply due to distraction, as other irrelevant noise does not have the same effect (Colle & Welsh, 1976; Salamé & Baddeley, 1982). Use of the irrelevant speech effect would avoid the problem of dual task demands, and it would enable researchers to disrupt the self-directed speech of younger children who are not able to dual-task. Therefore, although the dual task methodology represents a very valuable step forward, there is still room for improvement in terms of research of experimental design on self-directed speech.

6.3 Concluding remarks

The last two decades or so have seen some significant developments in research on self-directed speech, both methodological and theoretical. This chapter has outlined the contribution of the present thesis to current debates, and has discussed in detail just a few of the issues that will be facing researchers in the immediate future. There is a lot still to be learned about self-directed speech in both typical and atypical development, and every reason to believe the next 20 years will be just as exciting as the last.

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