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VALDAR TAMMIK

RELATIONSHIPS BETWEEN DOMINANT STRUCTURE OF WORD MEANINGS AND VISUAL FIGURE DISCRIMINATION

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CONTENTS

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INTRODUCTION

This thesis deals with the relationship between verbal thinking and visual search. Although verbal and visuospatial reasoning are often seen (and not without justification) as relatively independent in psychology (Paivio, 2014), there are both theoretical arguments as well as empirical evidence to question this view, e.g., the facilitative effect of language in supposedly visual tasks (e.g., Lupyan, 2008; Lupyan & Ward, 2013; Lupyan & Thompson-Schill, 2012) and interactions in even low-level processing (e.g., Chabal & Marian, 2015; Zwitserlood, et al., 2018; see also Ogilvie & Carruthers, 2016).

The fact that there is *some* relationship is not very interesting in itself, however. The real question is about the nature of that relationship: what role(s) does language play in the functioning of the mind in general, and in visual processing in particular. This thesis embarks from a specific – Vygotskian – theoretical background and investigates this issue on a large adult sample using a specifically designed verbal task and a well-known neuropsychological task requiring visuospatial analysis of a scene. The core of the argument being that these two tasks have, at face value, little in common but are expected to be correlated based on the theory. If a relationship is established, it offers some support for the theory that predicted it or at least calls for an alternative explanation that can then be pitched against the current one in subsequent studies to drive the understanding forward.

As the issue being investigated here is an aspect of the broader question regarding the role of language in mind, which has a controversial history, I will start with a brief overview and clarification of that topic; this will be followed by my personal position, the specific research question, and an overview of two empirical studies along with a theoretical one. The thesis ends with a discussion and summary.

1. THEORETICAL FRAMEWORK

1.1. LANGUAGE AND MIND

"Current discourse on the topic of language and mind is at about the intellectual level of a chat show on the merits of democracy. Ideological nonsense, issued by famous scholars, fills the air, even the scientific journals."

S. C. Levinson (2003, p. 25)

The question about the relationship between language and cognition has a long history of research and debate but has remained controversial. Positions on the matter are ranging from,

"Language may be useful in the same sense that vision is useful. It is a tool for the expression and storage of ideas. It is not a mechanism that gives rise to the capacity to generate and appreciate these ideas in the first place." (Bloom & Keil, 2001, p. 364).

to,

"Perhaps the kind of mind you get when you add language to it is so different from the kind of mind you can have without language that calling them both minds is a mistake." (Dennett, 1996, p. 17).

The question whether language interacts with thought is, as such, not controversial. The fact that it does is clear from our everyday experience as well as from scientific research. What is controversial, is the way and extent to which it does so, as well as its significance. There is a quote from Devitt and Sterelny (1987, p. 178) that has been sometimes referenced as an example (e.g., Gentner & Goldin-Meadow, 2003; Lupyan, 2012): "The only respect in which language clearly and obviously does influence thought turns out to be rather banal: language provides us with most of our concepts." Here it is claimed that language has but a limited role in cognition; yet that role is to provide the very building blocks for thought. I find nothing banal about such a function of language. On the contrary, this claim actually goes further than many researchers working on the topic would dare to go. Concept development is usually seen as a complex process involving far more than language and it also has to be possible without language. How would it otherwise be possible to acquire language in the first place? Claiming that language provides most of our concepts is thus quite strong. Statements like this, however, highlight the core of the problem: differences and lack of clarity regarding the fundamental concepts, i.e., what is meant by language and what is meant by mind/thought/cognition. It consequently becomes unclear what counts as a "real" and interesting effect of former onto latter or whether this is even an adequate way to pose the question.

Leaving aside the nuances, at least the following broad positions on the matter can be distinguished in the literature[1]:

1. Language is a system for communication that has little to do with *underlying* thought, a view explicitly defended by Paul Bloom & Frank Keil (2001) and Lila Gleitman & Anna Papafragou (2005; 2013), for example.

This theoretical stance largely stems from linguistic nativism and innate semantics (most notably associated with the works of Noam Chomsky and Jerry Fodor). It defends the nativist assumption by pointing to the curious similarity between the world's languages, and speakers of these, and claims that it is difficult to explain the rapid acquisition of language by children without it. Additionally, it claims that the general richness of thought would be hard to explain without assuming more fundamental underlying mental structures and processes that are less rigid than the language that *reflects* them. This in turn is seen as making it logically impossible for language to have a central transformative role in the mind.[2] As it is a "negative" position that denies a fundamental role of language in mind, the defense often lies in dismissing the arguments and empirical findings of others. Whilst it accepts there are demonstrable interactions between language and cognition, these are dismissed as trivial, i.e., not demonstrating any *fundamental* role played by language. This seems to be the most popular or "default" position in psychology currently.

2. Language has an effect on thinking (at least) to the extent that if one needs to express oneself in a certain way, they need to think in that way (during the act of communication); practice of thinking in a specific way to communicate has general transformative consequences beyond these communicative contexts. This view is most notably associated with Dan Slobin (1996) when confined to communicative context and with other researchers in the anthropological tradition like Lera Boroditsky (2001) or Stephen Levinson (2003) when taken more broadly.

The evidence for the position comes from the observation of an astonishing variability in languages worldwide (Evans & Levinson, 2009); and the logical argument that these often impose a particular way of thinking. If certain linguistic distinctions are mandatory in a language then people are forced to think about these distinctions (if they want to communicate) which has general consequences. This claim is backed by empirical findings that show biases in cognition between speakers of different languages along the characteristic encoding patterns of their native tongue. This has been demonstrated across a number of contexts, for example in the areas of motion events (Slobin, 1996), categorization by shape versus material (Lucy & Gaskins, 2001), memory of agency (Fausey, Long, Inamori, & Boroditsky, 2010), spatial reasoning (Haun, Rapold, Janzen, & Levinson, 2011), quantity estimation

[1] The specific researchers associated with each position are for illustrative purposes only and the actual positions of the researchers are, of course, more nuanced and specific than the crude statements here. Also, the categories are in reality not as clearly separable as presented here, with most researchers endorsing a combination of points from these.

[2] All of these claims have, of course, also been contested.

(Frank, Everett, Fedorenko, & Gibson, 2008; Gordon, 2004, see also Frank, Fedorenko, Lai, Saxe, & Gibson, 2012), and even color perception (Roberson, Davidoff, Davies, & Shapiro, 2005).

Proponents of position 1 argue that these effects, while genuine, do not demonstrate any fundamental effects of language on cognition. Some of the effects are confined to the linguistic domain. That is to say that it is linguistic processing that brings these effects about; removing the linguistic context also removes the effects (hence no fundamental transformation has taken place). Furthermore, the causality could work in the other direction. A culturally shared preference can manifest in language — rather than be driven by it — and come from frequency of thinking in some way rather than language *per se.* Also, some effects are just preference-biases with minor implications as they are easily reversible. In sum, critics argue that although there obviously is some interaction between language and cognition, these effects do not demonstrate any fundamental changes in the mind due to language.

3. Language is a "tool" that can be recruited to aid thinking, and some types of (characteristically human) thinking become possible only through the help of this "tool". This is view is endorsed by Andy Clark (1998), Dedre Gentner (2003; 2016), and Elizabeth Spelke (2003), for example.

The emphasis here is usually on new possibilities in thinking due to language and the empirical evidence presented with this view mostly comes from developmental psychology: from studies demonstrating parallels between developing language and cognitive abilities (Gentner, 2016; de Villiers, 2014) and from natural experiments of abnormal language acquisition due to external circumstances (Gentner, Özyürek, Gürcanli, & Goldin-Meadow, 2013; Spaepen, Coppola, Spelke, Carey, & Goldin-Meadow, 2011; see also Luria & Yudovich, 1971). Another line of developmental evidence comes from self-directed speech: talking to oneself seems crucial for children's problem solving during certain period in development and then disappears, arguably because of being internalized (see Berk, 2014; Winsler, 2009, for research overviews). Of course, the previously mentioned evidence from cross-linguistic studies is relevant here as well.

Opponents argue that there are some *underlying* cognitive capacities that develop and that this is just *reflected* in language — *not driven* by it. Also, it is argued that the use of language as a cognitive "tool" in some contexts is just a trivial fact and thus, not interesting in regards to the "thought and language" debate that is supposed to be about language *transforming* thought. Additionally, studies with very young children are especially easy to attack on methodological grounds (as it turns out that experiments are hard to conduct and interpret when you cannot *talk* with the participants).

4. Linguistic representations play a *central* role in human cognition by constantly modulating ongoing cognitive processing, a view endorsed by Gary Lupyan (2012; 2016), for example. There is also a "softer", modular, form that posits more limited

interaction and effectively becomes the same as the previously introduced, "tool" view (e.g., Frank et al., 2008; 2012).

This position aims to do away with the sharp distinction between linguistic and non-linguistic processing. Compared to the previous views, the emphasis here is on *online* interaction between linguistic and other representations rather than overall qualitative changes related to language. The empirical evidence comes from studies where some supposedly non-verbal cognitive processing is shown to be affected if the involvement of language is experimentally up- or down-regulated (which should not happen if the processes were independent). For example, it has been demonstrated that color discrimination is faster if target and distractor colors have different names, but only in the right visual field and this effect disappears with verbal interference (Gilbert, Regier, Kay, & Ivry, 2006). In a similar vein, it has been shown that picture verification is faster when the item is queued by a word versus the characteristic sound it makes (Lupyan & Thompson-Schill, 2012) and concepts are acquired faster when the novel category to be learned is labelled versus not during learning (Lupyan, Rakison, & McClelland, 2007).

The counterarguments go along the same lines as previously: that the studies are not proving that language has any fundamental *transformative* role in cognition, just that it is involved in some way online (i.e., transiently).

5. Acquiring language transforms thinking into fundamentally new (higher-order) forms and is essential for certain characteristically human traits, including (self)consciousness[3] (e.g., Toomela, 2003; 2015; Vygotsky, 1934/1986; Vygotsky & Luria, 1994).

The empirical evidence here is mostly the same as for the previous positions, especially the "tool" view, and the contrast lies in interpretation and theoretical considerations. This position will be clarified further in the next section of the thesis as the one I endorse.

As for the question of "linguistic relativism" (the general position that the language we speak affects the way we think, conventionally associated with Benjamin Lee Whorf): position 1 denies it, position 2 endorses it (in a soft form), position 4 also endorses it (although the research tradition does not focus on it much), while positions 3 and 5 are more concerned with general aspects of language (i.e., language as such) and so the contrasts between specific languages get less attention.

While the above list might seem like a continuum of positions regarding the magnitude of effect of language on mind, it is *not*. These research traditions are often dealing with different, though complementary, issues. For example, while there are many important questions regarding the ramifications of specific features between languages, understanding the role of language in and of itself is another matter. The difference is in focusing on the characteristics of language that are free to vary as opposed to the defining ones and the respective implications of these. Also, while

[3] Consciousness is here conceptualized as the experience of one's own mind.

some researchers study *online* (transient) effects related to language, others are interested in transformative changes through the first few *years* of development. It is far from obvious how these two levels of analysis interact. Additionally, while many researchers focus almost exclusively on words (as labels), others argue that, taken as such, this unit of analysis does not really *exist,* so the research programs require considerable revision of scope (Lucy, 2010). Finally, while the main aim of some researchers is to understand the role of cultural (especially linguistic) "artifacts" in cognition (Vygotsky & Luria, 1994), others dismiss relevance of experimental findings with arguments such as: *"For one thing, subjects might explicitly use their linguistic knowledge when doing the similarity task."* (Bloom & Keil, 2001, p. 356).[4,5] This demonstrates a striking difference regarding what is considered relevant to the discussion to begin with.

In sum, the positions (with the exception of the first one) are often more complementary than contradictory. They often start from very different assumptions, though, and that might also explain their relative independence and lack of theoretical integration.

A further complication in the discussion is the issue of *development,* which is relevant in at least two different ways. On the one hand, it is possible that language is needed and has a profound effect on the developing mind that might be different from the role it plays in the mature mind. For example, we might learn some concepts and thinking strategies through the help of language, but once acquired, their use might be independent from (either implicit or explicit) use of it. On the other hand, the use of language itself develops and, if there is a role language plays in cognition, then this might change accordingly. Furthermore, it is likely that *seemingly* the same language constructs can be internally different. For example, the same word can acquire a fundamentally different *meaning* (i.e., relationship with other concepts) to a person over time. This adds another dimension to "linguistic relativity": the question then is not only about cognitive differences related to distinct languages but also between (inter- and intraindividual) uses of the "same" language. This issue is especially apparent in relation to language acquisition, but is in no way logically restricted to it.

The questions do not end here, but it is hopefully apparent that the issues are complex and manifold and the assumptions of some researchers so fundamentally different

[4] In other words, while for one, the fact that the addition of symbolic representations to the cognitive system changes the way the task is solved *is* the fundamental point; for another this is a nuisance that disrupts observation of language having a "real" effect on some "pure" (non-linguistic) thinking.

[5] As a side note, positions 1 to 3 are probably also (at least implicitly) underlying the strong distinction between verbal and nonverbal thinking/IQ prevalent in psychology. If linguistic representations are seen as just a special type of representations needed in expressing oneself or recruited on demand, then manipulating them can be a relatively distinct activity from thinking in general; if language occupies a more central role in the mind, then such a distinction becomes questionable, however.

from others to be effectively incommensurable. The integration of the field is beyond the scope of the current thesis, but I hope the above shows that a reasonable addition to it warrants spelling out the underlying assumptions and positions one starts with. It is needed to assess the conceptual consistency of the claims as well as the (ir)relevance of other positions/arguments. Before moving on to my empirical research and the specific question motivating it, I will therefore briefly state my view on the question of "language and mind".

1.2. AUTHORS' POSITION ON LANGUAGE AND MIND

"The relation of thought to word is not a thing but a process, a continual movement back and forth from thought to word and from word to thought. In that process the relation of thought to word undergoes changes that themselves may be regarded as development in the functional sense. Thought is not merely expressed in words; it comes into existence through them."

L. S. Vygotsky (1934/1986, p. 218)

The position regarding the interplay of language and mind I endorse is formulated by Aaro Toomela (2016; 2017;[6] a short summary focused on the developmental aspect can be found in Toomela, 2003) and draws heavily on "cultural-historical psychology" as established by Lev Vygotsky (Toomela, 2015). From the previous enumeration of positions, it is in the fifth – language transforms thinking into fundamentally new forms – category. What follows is a short summary of the theory.

1.2.1. Language

Language is viewed broadly as a system of *symbols*; and anything directly perceivable through senses can become a *symbol* if it acquires a *conventional* relationship with its referent (either sensory representation or another *symbol*). *Conventional,* here meaning that there is no inherent reason for such a reference-relationship and that the *symbol* can be "used" differently from its referent. In short, the defining characteristic of linguistic representations (*symbols*) as opposed to purely perceptual ones, is that the latter follow the rules of the natural world, whereas the former follow the rules of the social world. This distinction is crucial because *thinking* (defined as internal organization of knowledge) would be fundamentally tied to the observable regularities of the world (in addition to innate processes) if it were not for symbolic representations that free it from these constraints (Toomela, 1996a; 1996b; see also Nelson, 2005; Homer & Nelson, 2005, for similar arguments).

Developmentally, representations that eventually become symbols start out as "natural" representations no different from any other sensory based ones, but diverge through a child's interaction in the social environment. The first "words" of the child

[6] As of this writing, these books are available only in Estonian, but English translations are in the works.

are not actually words (as symbols) in the true sense. They are just learnt associations between some experiences — a characteristic marker (e.g., a sound) and some situation in the world — and are thus very tightly tied to the specific context they are associated with. That is, they are *indexical* rather than *symbolical* (in Peirce's terminology) with the crucial difference being that the relationship is empirical rather than conventional. Importantly, however, they are considered and used as words in the true sense by the adults around the child. That offers the child ample opportunities to gradually learn the difference between words and other properties of the situations experienced.

For example, the sound "mommy" starts out as a simple association, but then acquires a new role when the child learns to *produce* it to bring about changes in the world: to summon or guide someone's attention to their mother. Whilst appearing quite sophisticated, such use can initially rely on very simple associative learning. However, it creates the possibility to start differentiating between the *social* aspects of the use from its *referential* aspect: the specific sound acquires a dual quality unlike other representations that are always directly tied to the referent without any truly social aspect. It is in the synthesis of these two qualities of the utterance — the referential and the social — that a word in the true sense (as *symbol*) is born. This usually happens in the beginning of a child's second year of life and is followed by a long road of further differentiation and synthesis of different kinds of words (Toomela, 2003; 2017).

Central in this differentiation are the social aspects, most noticeably *grammar,* which determines the *conventional* rules to be followed in using and combining words in order to communicate. The sound "mommy" is, in the end, no longer just an equal part in some associatively learnt idiosyncratic representation related to the caregiver. It is a *noun* that can refer to not only the specific person but also to other women in a similar role; it is a synonym for mother, and can be combined with other words to create entirely novel categories. For example, "Holy Mother" that could not be constructed from direct experience and might not have a perceivable referent at all.[7]

At the same time, the realization that words can be used in the social context to influence peoples' actions or guide their attention, paves way for mastering the same mechanisms to guide one's own actions, too (Vygotsky, 1934/1986; Vygotsky & Luria, 1994). This is most evident in the well-established phenomenon of self-directed speech that clearly seems to have a self-regulatory performance-enhancing function and is readily found even in adults (see Berk, 2014; Winsler, 2009; for reviews). It is proposed that this is the very mechanism (in tandem with the increased self-consciousness due to symbolic representations) that forms the basis of (voluntary) self-regulation (Vygotsky & Luria, 1994), a claim that is supported by

[7] There of course exists a referent just as with any other word: a word is a mental representation built on other mental representations and what a word "refers to" is the totality of its (potential) relationships to other mental representations. So, strictly speaking, it does not "refer to" anything at all, but rather "it is"; and it most certainly does not "refer" – in the direct sense – to anything outside the brain.

correlational relationships, as well as experimental studies (Lidstone, Meins, & Fernyhough, 2010; Luria, 1959; Müller, Jacques, Brocki, & Zelazo, 2009).

Self-directed speech follows an inverted-U pattern — from none to overt to covert — in relation to age and task demands. At first the frequency of private speech increases — especially in demanding situations — and later on declines, though never fully disappearing (Fernyhough & Fradley, 2005; Montero, 2006; Winsler & Naglieri, 2003). The transition from overt to covert is also characterized by changes in the speech's structure, most notably its condensation. This provides further support to the idea that it gets "internalized", i.e., becomes part of automatic thinking processes different from and no longer requiring the overt communicative component (Vygotsky, 1934/1986; see Alderson-Day & Fernyhough, 2015, for a review of recent research on inner speech).[8] This phenomenon, expectedly, is in no way restricted to children; as best demonstrated by studies with adults exposed to varying levels of formal education: self-regulatory private-speech is predicted by literacy and task demands akin to the effect in children (Alarcón-Rubio, Sánchez-Medina, & Winsler, 2013).

It is noteworthy that, one the one hand, it is again the social interaction that is needed to establish the behavioral patterns that later on subsume a different, *intra*psychological role; on the other hand, it is again — and not incidentally — language that plays a special part. And why language? Because of the above mentioned dual character that allows for more flexible use compared to non-linguistic representations: in this case as self-produced stimuli (to oneself).[9] This, in turn, enables the further differentiation of the communicative function into the inter- and intrapsychological ones. It is in this sense that the social aspect of the symbol is crucial and frees the mind from the constraints of immediate impressions of the world. It sets the stage for mastering one's own mental processes and discovering rules of thought different from the rules of experience. No matter the properties of the thing the word represents, words have their own rules one needs to master as well, and these rules need not respect the boundaries and context of the immediate sensory experiences.

[8] Note that it does not follow from this that thinking is somehow reduced to speaking to oneself. Language plays a transformative role in interaction with sensory representations: through the inclusion of language-based representation, the sensory ones are transformed not subordinated. The general principle of automaticity (Logan, 1985) applies here as anywhere: what is intentional and effortful in the beginning becomes automatic and effortless through practice (when the synthesis of the representations is complete). This is in line with the studies on self-directed speech as well as those using verbal interference, for example. As noted by Lupyan (2016, p. 528) when discussing the latter: *"[…] a better way of thinking about verbal interference is that it interferes with otherwise automatic (and largely covert) linguistic processes"*.

[9] More precisely, language that has so far served a communicative role acquires a general *mediative* role in cognition (Toomela, 1996a).

1.2.2. Development

Symbols (i.e., their meanings), as alluded to before, *develop*, and, accordingly, so does the cognition that encompass them. But what does it mean to develop? *Development* is generally defined as hierarchical reorganization of a system. This can happen, either through integration of new elements into its structure, or a change between the relationships of existing ones, which results in the system having new and/or changed properties. We have already seen this principle in action in the case of first words, where an initially perceptual representation differentiates through active participation in the communicative context into a referential and communicative one to be later synthesized into a new whole: a true word that carries a meaning outside communicative context and is not entirely tied to the initial referential boundaries.

Word meaning structure can pass through (at least) five such cycles of differentiation and synthesis resulting in a transformed structure. Two of these are important here: the "everyday" (also called "spontaneous") and the "scientific" (or better yet, the "logical")[10] (Toomela, 2003; 2017; Vygotsky, 1934/1986).

Everyday/spontaneous concepts are formed based on everyday experience with the words and their referents. A word in this stage can refer to a plethora of things that can all have a different reason for belonging to the category: an aggregate or collection of the related impressions *is* what the word means. For example, the word "mother" could refer to any mother one has had experience with, as well as the *salient* properties they have had in common in these interactions. The exact reason behind the perceived "salience" among the defining characteristics is idiosyncratic and not consciously accessible to the person. That makes the exact boundaries of such categories ever changing and fuzzy. As the abstractive mechanism behind these is fundamentally tied to specific experiences, so too are the categories themselves, even when they *appear* very abstract. There is ample evidence to suggest that children's words (and corresponding categorizations) really do have this sort of character (e.g., Lucariello, Kyratzis, & Nelson, 1992; Nelson, 1977; Scheuner, Bonthoux, Cannard, & Blaye, 2004; Sell, 1992).

Scientific / logical concepts, on the other hand, are structured within language: words that refer to other words (which, in turn, refer to either words or sensory representations). This relationship makes it possible to *define* words, i.e., in contrast to aggregate experience, we are dealing with word-hierarchies and it becomes possible to say exactly what a word means; for example, to define "mother" as a female parent. This is important because with scientific / logical concepts, the mind truly transcends everyday experience and true logical thinking becomes possible. This is so because in order to define something, one needs to be able to *consciously*

[10] "Scientific concept" is a misleading term because these types of concepts need not have anything to do with science: it is the internal structure, *not* the relationship to the cultural practice that matters. Furthermore, concepts found in science are not necessarily "scientific concepts" in this specific (structural) sense.

abstract away the crucial aspect of the category, as well as the distinctions between individual members of it[11]. Staying with the previous example, as "mother" is a female parent, she necessarily needs to share certain defining properties with all parents, yet be distinct (at least) in being female (which in turn necessarily implies that there are other possibilities). It is only with this kind of linguistically-structured representations that a mind can truly reflect itself and the properties of its own operation: it becomes possible to deliberately compare and contrast concepts within language and discover inconsistencies or implied conclusions; i.e., it becomes possible to think logically. The true abstraction (e.g., conscious principles of categorization) allows thinking to transcend the final ties with experience-based impressions.

For example, even pre-school age children can draw perfectly "logical" conclusions in contexts that do not conflict with their experience, but this ability breaks down as soon as it does (Hawkins, Pea, Glick, & Scribner, 1984); and the same applies to adults with limited formal education (Dias, Roazzi, & Harris, 2005; Luria, 1976). Even well-educated adults do poorly on tasks requiring formal logical thinking and markedly better when fundamentally the same tasks are reformulated or presented as everyday situations (Cheng & Holyoak, 1985), which indicates that these cases are solved differently. This brings us to an important consideration: *heterogeneity* and *stability* of the representations.

On the one hand, structurally higher kinds of representations do not replace previous ones but transform them. So, despite being able to, e.g., define a word, all the perceptually learnt associations, impressions, and connotations remain; and new words can of course be learnt in the same way as existing ones by going through all the same stages. On the other hand, when language-competence is developed enough, it becomes possible to further develop it through different means – most notably by explaining and analyzing word meanings using other words, i.e., learning words through words. For example, while it would not be difficult to learn the meaning of the word "sirocco" purely from experience living in Sicily, it is immediately understandable regardless of any direct experience when defined as "a hot dust-laden wind, blowing from North Africa across the Mediterranean to southern Europe"; personal experience does significantly enrich the concept, however. This means that the mind is inherently heterogeneous: structurally more developed concepts live side-by-side and interact with more primitive ones and the specific meaning of the concepts activated is dependent on both context and their developmental history (Lin & Murphy, 2001). This makes experience (i.e., practice) a crucial factor to take into account as it takes time before the representations acquire a certain stability (e.g., Scheuner, Bonthoux, Cannard, & Blaye, 2004).

An interesting phenomenon that might be explained through this heterogeneity is the "foreign-language effect", where people are more resistant to irrational cognitive biases when they make decisions in a foreign language as opposed to their native

[11] *Consciously* refers to the fact of being aware of being aware of it, i.e., being able to reflect on it.

tongue (Costa, Foucart, Arnon, Aparici, & Apesteguia, 2014; Keysar, Hayakawa, & An, 2012). Although Costa et. al. (2014) did not find the effect on tasks requiring formal logical reasoning (Study 4), it is noteworthy that counterfactual syllogistic reasoning in children manifests itself earlier on tasks that have foreign rather than familiar (everyday experience related) content (Hawkins, Pea, Glick, & Scribner, 1984). These effects are presumably due to interference from everyday experience-based representations that make the formal ones harder to maintain (see, e.g., De Neys & Franssens, 2009). This interference is lessened with foreign content as well as foreign languages that were learnt in a classroom setting that is known to rely heavily on the already developed native tongue and hence, less likely to induce as many experiential associations. Other content effects in logical reasoning could work through similar mechanisms. For example, logical judgments regarding causal effects being heavily influenced by the number of (real-world) alternative causes and disabling conditions available (Cummins, Lubart, Alksnis, & Rist, 1991; Cummins, 1995).[12]

In sum, concepts (e.g., word meanings) develop over several stages. Based on the posited central transformative role of language in cognition, we would generally expect corresponding transformative changes in cognition. That said, development is not a simple, linear, all-or-nothing type of process; and even if general characteristics of the developmental change are established, it is not obvious how these general changes manifest in different contexts and cognitive domains more specifically. Furthermore, stability of the acquired changes is an important consideration.

1.2.3. Comparison to other views

So how does the described theory relate to the five general positions outlined previously? The relationship with the 5th position (language fundamentally transforms thinking into new forms) is clear: it is precisely this view that was described here. With the 4th position (language continuously modulates ongoing cognitive processing), I see no inherent conflicts, but there is a clear difference in focus. While Lupyan and others, in what could be called the "cognitive science" tradition, are most interested in the ongoing processes in the developed mind/brain and modeling these, the social and developmental aspects central to the current view assume secondary position there and *vice versa*. I see a clear complementarity between the approaches. The cognitive science tradition would gain from adopting

[12] For "if-then" causal claims, alternative cause is simply some other (i.e., non-cited) cause and disabling condition is something that could prevent the effect from occurring. As an example, consider these two claims (Cummins, Lubart, Alksnis, & Rist, 1991, p. 276):

1. If my finger is cut, then it bleeds. My finger is bleeding. Therefore, my finger is cut.
2. If I eat candy often, then I have cavities. I have cavities. Therefore, I eat candy often.

Both of them are deductively invalid but people are more inclined to accept the first one, presumably because there are few alternative causes for a finger to bleed but many for having cavities.

more structural-developmental[13] approaches, and the Vygotskian tradition would gain from elucidating the exact mechanisms underlying many of the phenomena more specifically (e.g., behind the differentiation and synthesis or stability and interference between representations), including on the neural level.

Regarding positions 2 (language has its effect through attention-guiding and habit-formation) and 3 (language provides cognitive "tools"), there is again no general conflict with the current position (and often quite on the contrary). There is usually considerable vagueness regarding the fundamental concepts (such as language), however, which results in overall fragmentation and lack of theoretical integration of different research traditions in this category. In other words, despite many interesting empirical findings and "local" theories, the research seems to be held back by not elucidating the most fundamental concepts, thereby making it hard to integrate and many of the findings remain "hanging in the air" or acquire quite opposite interpretations by different authors.

As for position 1, i.e., the counterarguments of the skeptics, to put it bluntly, I think they often miss the point. As a recap: we claimed that over the course of our cognitive development, the initially communicative role of language assumes an *intra*psychological role by providing new *kinds* of representations. These are fundamentally more flexible due to their representational-communicative dual character and especially relevant for self-regulation (as self-generated stimuli to oneself). Thinking — defined as internal organization of knowledge — is affected because representations are the building blocks with which it operates.

Now an example from the arguments of Bloom and Keil (2001) to support their conclusion, *"Probably not"* to the question *"Does language have a dramatic influence on thought in some other way than through communication?"* (pp. 363-364). When discussing cross-linguistic effects: *"As Lucy and Gaskins suggest, their findings are consistent with the view that judgments of similarity are shaped by the language one knows. There are alternatives, however. For one thing, subjects might explicitly use their linguistic knowledge when doing the similarity task. That is, they use the strategy of naming the target object to themselves and then look towards the other objects and see which get the same name. Alternatively, the effect might be due to cultural factors independent of language"* (p. 356). As a general point: *"We need to consider more carefully the differences between tasks that are language-dependent and those that are language-free. If the task itself requires that the person use inner speech, for instance, then any effect of language on performance is considerably less interesting"* (p 358).

[13] By the structural-developmental approach, I mean explaining phenomena through elucidating the underlying structure (i.e., the components of the system with their interrelationships giving rise to the phenomena) *and* the development of it (i.e., how did it came to be). Explaining the nature of *word* as a specific kind of representation formed through differentiation and subsequent synthesis of communicative and referential aspects of a perceptual representation (described above) would be an example of applying this principle. See Toomela, 2003, for a longer discussion.

The authors do not bother to define language nor thought, but the fact that a task necessitates the explicit use of linguistic knowledge or inner speech, are to them, clearly not examples of language having a dramatic influence on thought. What they want, apparently, is *thinking-independent language* which, after having done its work, has left a lasting effect on *language-independent thinking*. Based on the theory and definitions outlined above, this is unjustified: language exerts its effects either through active participation in thinking or through its assimilation into existing mental structures — after which, the representations are not language-independent anymore. It seems to be the *assumption* of independent language and thought "modules" that underlines the position of Bloom and Keil in the first place. However, this assumption is, from the position argued here, simply unfounded. Most other arguments of the skeptics are built on similarly dubious assumptions, such as the fundamental homogeneity of world languages (Evans & Levinson, 2009) or "*Language Learning as Mapping"* (Lupyan, 2016).

Overall, I think, most of the disagreements come down to *implicit* assumptions and definitions that create a lot of false controversies or dead ends. The most fundamental differentiator of the view championed here compared to most of the others, is perhaps the structuralist-developmental approach: for Vygotsky, Luria, and Toomela, the most crucial aspect in understanding something, is describing its structure and answering the question, "how did it came to be?". Many of the current researchers, either implicitly or explicitly, seem to draw on essentially nativist assumptions and seem happy to explain phenomena as unfolding of some innate processes. What is usually lacking though, is explicating the said processes, i.e., specifying what are the biological mechanisms that are innate[14] and how does the unfolding relying on them work. Positing that something (e.g., language) is innate and then labelling the empirical observations is not explaining the phenomena: it is just naming the phenomena to be explained — a surrogate for a theory (Gigerenzer, 1998; 2009). This sometimes goes hand-in-hand with seemingly mindless accumulation of empirical relationships to be labelled, probably due to another questionable assumption that this is what scientific theories are about (Lewin, 1931; Tammik, 2014).

Toomela's theory provides an overarching and biologically plausible framework for thinking about the mind and the role language plays in it, but is inevitably generic, i.e., it specifies the general mechanisms and characteristics of the language-mind interaction in its development, but does not specify how it manifests in different cognitive domains and contexts more specifically. Explicating this is left for ancillary research and this study aims to take some steps in fulfilling this in the context of visual perception.

[14] And *only* biological system can be innate as the *mind* is formed through its interaction with the environment.

1.3. LANGUAGE AND VISUAL SEARCH

"From the first steps of the child's development, the word intrudes into the child's perception, singling out separate elements overcoming the natural structure of the sensory field and, as it were, forming new (artificially introduced and mobile) structural centres"

L. S. Vygotsky & A. R. Luria (1994, p. 125)

The way in which vision interacts with higher-level conceptual knowledge, including language, has been of continued interest in psychology, but the exact nature of this interaction has remained controversial (Collins & Olson, 2014). At large, at least three different levels of interactions can be distinguished.

On the first level, linguistic representations seem to be invoked by and interact with ongoing visual processing automatically. For example, people are distracted by objects with phonologically similar names during visual detection of objects (Chabal & Marian, 2015). Similarly, visual scenes induce priming effects in subsequent action naming from photos (enhancing naming speed, if actions in prime and target scenes match and slowing it, if actions are unrelated but phonologically similar) (Zwitserlood, et al., 2018). Likewise, language input affects ongoing visual processing and exploiting this has even become an established research method in psycholinguistics: the "visual world" paradigm, where changes in visual scanning in response to linguistic input are used to shed light on the structure of the underlying representations and processes (Huettig, Rommers, & Meyer, 2011). In visual search and object detection tasks, using named labels has been shown to facilitate performance (Lupyan, 2008; Lupyan & Ward, 2013; Lupyan & Thompson-Schill, 2012) and the effect appears also when the linguistic input is self-generated in the form of self-directed speech (Lupyan & Swingley, 2012).

On the second level, general learning effects driven and supported by high-level concepts can be distinguished. We can take medical professionals who are trained in "reading" mammograms as an example (Nodine, et al., 1999). They can obviously see things lay people cannot and although the differentiator here is learning the visual discrimination (which could also be achieved through rote practice without the medical concepts and, indeed, by machine learning (McKinney, Sieniek, Godbole, et al., 2020)), such a learning only took place due to the established categorical relationship, i.e., the meaning ascribed to the patterns. Or consider chick sexing (i.e., determining the sex of recently hatched chicken): a commercially important and demanding perceptual task that used to be achieved through extensive practice, but can also be tackled surprisingly easily through simple heuristics, i.e., through explicitly *defining* the differential characteristics (Biederman & Shiffrar, 1987). The varying color discrimination patterns between speakers of different languages probably also fall to this category (Roberson, Davidoff, Davies, & Shapiro, 2005). Though these might be considered secondary effects, the fact is, the world is effectively seen differently by people due to their linguistically encoded domain knowledge. Of course, both of these examples are just specific cases that reflect how

people rely on their conceptual knowledge during continuous perceptual analysis of the world (e.g, Altmann & Kamide, 2007; Lupyan & Clark, 2015). That said, there *is* also a *specific* facilitatory effect of integrating semantic information (Gauthier, James, Curby, & Tarr, 2003), and even *labels as such* (Lupyan, Rakison, & McClelland, 2007), with perceptual representations.

On the third level, we have strategic affordances thanks to higher level concepts. Here I mostly mean analysis of visual scenes that becomes possible when sufficiently complex conceptual thinking is available, such as counting (Frank, Everett, Fedorenko, & Gibson, 2008; Gordon, 2004; Wynn, 1990; 1992) or geometry (Spelke, Lee, & Izard, 2010). Though it can also be as simple as conceptualizing ⊓⊔ and ⊔⊓ as rotated 2 and 5 (Lupyan & Spivey, 2008), which would not be possible without these concepts and would not facilitate performance without the interactions between perceptual and conceptual aspects of representations.

Naturally, these three levels interact with and reinforce one another (see Goldstone, Landy, & Brunel, 2011, for a longer discussion in a similar vein). For example, domain concepts can form a basis for an initial effortful scanning using an explicit strategy (third level) that can become automatized through practice (second level) and in turn, shape and reinforce the initial domain representations that interact dynamically and involuntarily with others (first level). Empirically, such differences in spontaneous scanning between experts and non-experts has been demonstrated in the areas of medicine (McCormack, Wiggins, Loveday, & Festa, 2014), mathematics (Goldstone, Landy, & Son, 2010), and arts (Vogt & Magnussen, 2007), for example.

Drawing on the general view presented in the preceding chapter, it might be expected that the nature of these interactions changes in accordance with the development of the linguistic representations. Some effects are obvious. For example, in order to analyze a visual scene along some geometric properties, one first needs to have learnt these concepts, which in turn requires certain sophistication in thinking in general: e.g., it is (theoretically) impossible to appreciate some geometric principles — such as that the sum of the interior angles of a triangle is always 180 degrees — relying on "everyday" type of concepts alone. Having gained access to these principles, in turn, means the possibility of guiding one's attention to aspects of a scene that was not possible before. One cannot notice that a composition follows the golden ratio without knowing what the golden ratio is, which, in turn, requires understanding the concept of ratio in general.

What might be less obvious, however, is the shift in conscious control over perception through this. Having abstracted some principles, they have become conscious[15], i.e., it has become possible to state and choose (at least generally) what is it that is attended; e.g., the content versus the composition of a photograph. Furthermore, attending to, e.g., the "sharp bump" versus the "angle" versus the "acute angle" likely refer to rather different representations related to the same visual input: moving from

[15] By *conscious,* I again mean reflected by the *psyche*: it is not enough to be able to apply the principle, having abstracted the principle means being aware of being aware of it.

the vague experiential representation to the abstract geometrical domain together with the affordances it brings[16]. So, it could be speculated that just as simple labels restructure the visual field by highlighting some aspects of it, so do abstract ones, only with greater clarity and flexibility regarding the goals of the perceiver. In other words, it is expected that with more abstraction in the linguistic domain, comes the possibility of making use of that also in the visual domain by aiding in its "deconstruction" as needed. The specific aim of this research was to test this hypothesis.

Types of tasks where this relationship between linguistic concepts and visual perception would be expected to manifest is overlapping or embedded figures: tasks in which a small figure is "hidden" within a larger one by either many intersecting lines or when the lines are shared (see Figures 1 and 2 for examples). On the one hand, such tasks create an overburdening of the visual scene; on the other hand, they elicit automatic visual responses (some figures "pop out") that need to be overcome in order to find the target figure. It is well established that such tasks present difficulties for children (Ghent, 1956) as well as for adults in case of brain pathology or due to aging (Capitani, Sala, Lucchelli, Soave, & Spinnler, 1988; Sala, Laiacona, Trivelli, & Spinnler, 1995), although the exact reasons are still unclear.

Importantly, these tasks do not involve an obvious linguistic aspect, but according to the view presented above, we would expect that it is precisely the linguistic concepts that support overcoming the automatic response and deconstructing the scene into a more manageable one. The relationship is not expected to be a simple all-or-nothing one, though. This is due to several reasons. Firstly, because of the heterogeneity of mind discussed before, it is expected that people manifest more sophisticated thinking in some contexts, whilst simpler ones in others: having the potential does not mean it is always employed. Secondly, there are many aspects involved in solving any cognitive task and the visual tasks introduced above are no exception: while the "analytic" aspect may be important, there are also several independent perceptual aspects at play that likely differ between people. For these reasons, we would expect a correlation between the characteristics of linguistic representations and performance on the visual tasks, but not necessarily great predictive power in each individual case. With that caveat in mind, this study embarked to test this hypothesis.

[16] It is important to keep in mind that the label does not reflect the internal structure of the concept so "acute angle" can also refer to the "everyday" concept, but in its true sense (as angle less than 90 degrees) it is only encodable as a "scientific" concept.

2. OVERVIEW OF THE STUDIES

2.1. AIMS AND RESEARCH QUESTIONS

The general aim of this research was to test the Vygotskian hypothesis regarding the general transformative role of developmentally different types of concepts in cognition; more specifically the role of logical/scientific concepts in visuospatial processing.

The specific research question was whether the performance in visuospatial search is related to the propensity of using scientific/logical concepts as distinguished by Vygotsky (1934/1986).

This relationship should appear using a task which, at face value, seems to have little to do with verbal processing. It would best be demonstrated in adults because the theory makes no distinction in regards to age, but confirming this in an adult sample would allow us to easily exclude general maturational factors that could be at play in the case of children. Furthermore, the established relationship should go beyond a simple correlation to provide a stronger indication of a causal relationship.

2.2. METHOD

Both empirical studies used exactly the same method, with the difference being in the sample and analysis. The dominant word meaning structure (i.e., the propensity to use either everyday or scientific/logical concepts as distinguished above) and visuospatial performance on hidden/embedded figures was assessed and correlated in a large adult sample with varying levels of formal education. The second study extended the original sample of the first one with over a hundred additional participants over the age of 70 and looked for a specific differential pattern in the aging-related cognitive decline.

2.2.1. Participants

Participants of the studies were healthy Estonian adults with varying levels of formal education. The first study included 428 people between 17 and 69 years of age (mean 37.25, standard deviation 15) and were specifically chosen so as to encompass people with different backgrounds and educational levels. With one value missing, 163 participants had primary education (9 years or less), 149 had secondary education (12 years), and 115 had higher education (15 years or more).

The second study extended the original sample with another 119 participants over 69 years of age (mean 83, standard deviation 4.1). The combined sample consisted of 547 healthy Estonian adults from 17 to 97 years of age.

2.2.2. Procedure

Dominant word meaning structure, i.e., the propensity to use either everyday or scientific/logical concepts as distinguished above, was assessed using the Word Meaning Structure Test (WMST) that is comprised of 3 complementary parts. In the first part, one needs to define 6 concepts, half of them concrete (e.g., school) and half abstract (e.g. republic). In the second part, one needs to describe the similarity of six concept pairs, some sharing a category relationship (e.g. cat-dog), while others having a complementary relationship (e.g. horse-rider). In the third part, the participant is presented with six word-triplets (e.g. carrot-soup-potato) and asked to choose 2 that "go together" and explain why.

The answers (not the choices themselves) were coded as everyday concepts when the definition, similarity description, or reason for commonality was based on (a) sensory attributes (e.g. cat and dog are similar because both have four legs), (b) observations of everyday activities (e.g. school is where children go to study), (c) observations of everyday situations (e.g. carrot and potato go together because they both grow in the field), (d) description of function (e.g. typewriter and pen are both for writing), (e) sharing of parts (e.g. car and bicycle go together because both have wheels), or (f) no answer (because some items are not easily answerable without scientific concepts, e.g. the similarity between horse and rider).

The answers were coded as scientific concepts when (a) the relationship between words were defined hierarchically (e.g. horse and rider go together because they are both living creatures) or (b) the word was related to hierarchically higher-level concept (e.g. school is an educational institution). The maximum score (number of scientific concepts) in the test was 18.

Visual discrimination was assessed with two different contour picture tasks – Concrete and Abstract Contour Tracing Task (CACTT, Figure 1) and Situational Embedded Figure Task (SEFT, Figure 2). Both tasks require finding a small figure from a larger scene and were presented to the participants on paper with both the smaller and larger picture visible simultaneously.

The Abstract Contour Tracing Task (CACTT, Figure 1; adapted from Luria, 1980) is a modified version of the classic Poppelreuter's task (Poppelreuter, 1917) and requires the participant to find outline-drawings of common items among five overlapping ones. As a modification, abstract contours were added (as illustrated in Figure 1).

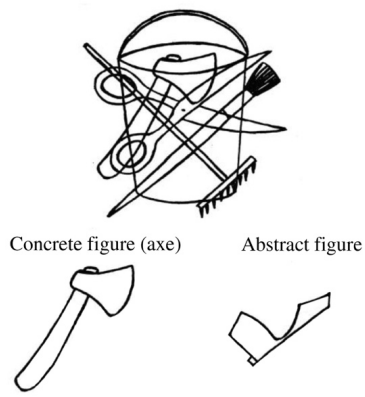

Figure 1. Concrete and abstract contour tracing task.

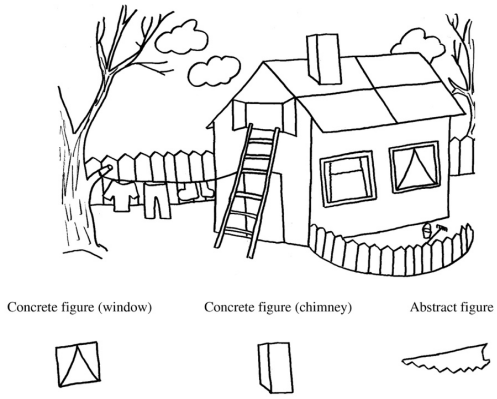

Figure 2. Situational embedded figure task.

The Situational Embedded Figure Task (SEFT, Figure 2) is, in principle, similar to the classic test by Gottschaldt (1926). Here too, one has to find small figures from a larger one, but this time, the figures are embedded in, i.e., share contours with, the larger one. In contrast to the classic test, the large figure in SEFT forms a meaningful scene (a house with garden) and, similarly to CACTT, both concrete and abstract figures need to be localized.

In the visual tasks, verbal labels were specifically avoided and participants were only asked to find *"it"*. There were no time constraints, and the participants were encouraged to try again if they gave up because we were interested in the ability not efficiency of solving the task.

All tests were administered as part of a larger neuropsychological test battery with the order of tests randomized between participants.

2.3. OVERVIEW OF THE STUDIES

2.3.1. Study I

The first study (Tammik, 2014) dealt with general issues of scientific practice in psychology, which, although not directly related to the empirical question, are especially important in a field as controversial as the study of the interplay between mind and language.

As a response to Smedslund and Ross (2014), the study analyzed the currently prevalent conceptualization of scientific research in psychology. The curious aspect of the position paper from Smedlund and Ross, which I claim applies generally, is that, despite very different questions and research traditions, the authors seemed to clearly agree on the general conceptualization of science (in psychology). The core

of this conceptualization is nicely captured by statements such as, *"[psychological research] necessarily provides not specific laws and formulae but generalizations based on the statistical analysis that consider mean tendencies and statistical significance of observed differences and associations"*. I argued that such a view of science, even if capturing the current practices in psychology, is not justified.

The argument was structured around the distinction between methods, methodology, and epistemology: epistemology is about justifying knowledge, methodology about justifying methods, and methods are the specific procedures to attain the knowledge (Carter & Little, 2007). These three levels are of course built on each other. It was argued that the conceptualization of the researchers, exemplified by the quote above, follows what was called "Aristotelian" epistemology by Kurt Lewin (1931). A key characteristic of this view, is seeing science as establishing laws based on the regularity of concretely observable cases. From this, it follows naturally that the (Fisherian) null hypothesis testing is appropriate and the usefulness of science is limited for psychological practice dealing with unique life histories of individuals.

This view was contrasted by Lewin (1931) to the "Galileian" epistemology in which the goal is seen in creating causal theories (as opposed to establishing empirical laws). The crucial distinction is between abstractions versus generalizations. Using Lewin's (1931, p. 150) example: *"The law of falling bodies, for example, does not assert that bodies very frequently fall downward. It does not assert that the event to which the formula* $s = \frac{1}{2}gt^2$ *applies, the "free and unimpeded fall" of a body, occurs regularly or even frequently in the actual history of the world. Whether the event described by the law occurs rarely or often has nothing to do with the law."* From this epistemological stance, the (Fisherian) null hypothesis testing makes sense only in specific circumstances or when no theoretical understanding is available or needed; apart from this, its relation to science is secondary at best.

It was concluded that the authors' view stemmed from this questionable conceptualization of science from which other issues followed, but our perspective is quite different when science is conceptualized more in line with the "Galileian" spirit, as it is usually done, for that matter, in more developed sciences.

2.3.2. Study II

The main aim of Study 2 (Tammik & Toomela, 2013) was to empirically test whether the hypothesized correlation between the verbal and visual tasks exists. A secondary aim was to discover possible subgroups of different performance profiles in relation to the two visual tasks.

The tasks were presented to 428 participants aged between 17 and 69, and the expected positive correlation was confirmed (with value around 0.35). The population level analysis was complemented with one at an individual level, configural frequency analysis more specifically, to identify possible subgroups of participants based on their performance. It was found that, although CACTT was generally harder than SEFT, there was a small subgroup of people for whom the

opposite was true. It was hypothesized that the specific complexity was related to the meaningfulness of the scene to be deconstructed, but it was not possible to confirm this. Additionally, it was found that women seemed to benefit less from advanced word meaning structure compared to men — perhaps due to differences in visuo-spatial working memory capacity (Kaufman, 2007).

2.3.3. Study III

The aim of the 3rd Study (Tammik & Toomela, 2017) was to put the relationship established in Study 2 to a more rigorous test by drawing on the concept of *cognitive reserve* (Stern, 2009). Cognitive reserve is a concept proposed to account for the discrepancy between brain pathology and its cognitive manifestation, i.e., the fact that people with similar levels of biological degradation can show surprisingly different levels of cognitive impairment. There are different mechanisms hypothesized to be responsible for this phenomenon, one of these being *strategic compensation*, i.e., changing the way the situation is approached cognitively (Lemaire, 2010).

In relation to aging-related cognitive decline, an interesting pattern regarding cognitive reserve emerges — as illustrated in Figure 3. People with poor compensation (i.e., low reserve), will start manifesting cognitive changes right away in line with the accumulation of aging-related neural degradation. People with good compensation (i.e., high reserve) can maintain a level of functioning for a time, but when enough degradation has accumulated, the compensational mechanism is no longer enough and the following cognitive decline will be rapid.

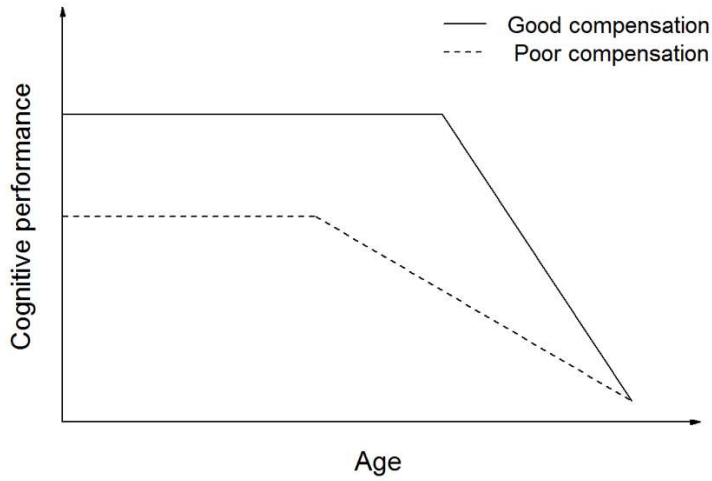

Figure 3. Cognitive compensation / reserve (adapted from Stern, 2009).

The relationship between the dominant word meaning structure and visual discrimination established in Study 2 was hypothesized to be due to scientific/logical concepts supporting deconstruction of the visual scene. As such, the dominant word meaning structure should be exactly the kind of strategic factor to support compensation of aging-related neural changes and if so, we would expect the pattern of cognitive reserve (Figure 3) to manifest between the tasks under consideration as well. Study 3 was conducted to test this expectation.

The original sample from Study 2 was extended with an additional 119 participants over 69 years of age, totaling 547 healthy participants between 17 and 97. The expectation was tested using piecewise (segmented) and local polynomial (LOESS) regression models and was confirmed (Figure 4).

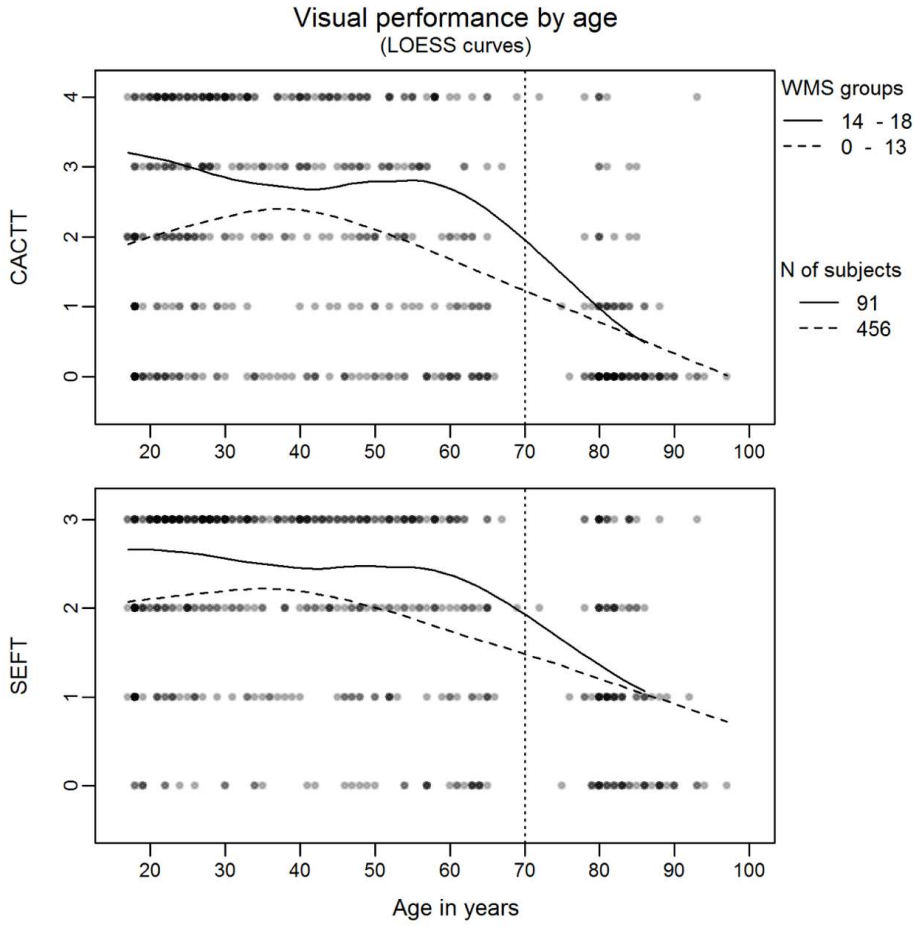

Figure 4. Results from Study 3. WMS groups based on the score in the Word Meaning Structure Test.

CONCLUSION

This thesis explored the interaction between linguistic representations and visuospatial reasoning. It started with a brief overview of the diverse viewpoints regarding the interplay of language and mind in psychology, with some elaboration of the one the author adheres to. This was followed by a summary of a theoretical study on current research practices and two empirical studies exploring the interaction between the dominant word meaning structure (i.e., the ability and propensity to operate with linguistic representation on the abstract, as opposed to the concrete level) and the ability to find figures embedded within a larger visual scene (see Figures 1 and 2, for examples). The theoretical justification for this, in short, was that despite not having an obvious linguistic aspect, solving these tasks should benefit from an analytical "deconstruction" of the visual scene that presumably requires operating with developmentally advanced linguistic concepts. As there is, arguably, no obvious connection between these tasks, establishing such a relationship provides some support for the posited theoretical position predicting it.

The expected relationship was empirically confirmed on a large sample of over 500 participants of varying ages and educational backgrounds: not only by establishing a simple correlation, but also by confirming a specific interaction pattern in relation to aging that was expected based on the theory (compare Figures 3 and 4). Although correlation provides relatively weak evidence in itself, the existence of a specific pattern related to *active* involvement is more compelling, especially since the test was not about speed but the *ability* to solve the task. These results thus provide some credence to the Vygotskian position and fit together with other studies demonstrating the relationship between (meta)linguistic and embedded figures tasks (e.g., Bialystok, 1992; Lefever & Ehri, 1976), which speaks against the strong distinction between verbal and visuospatial reasoning often held in psychology (Paivio, 2014).

To see what the results mean for the question of "language and mind" in general, it is instructive to consider how each of the previously introduced five perspectives regarding the question could view them. The 5th one — that language fundamentally transforms thinking — championed here, sees it as a nice (albeit indirect) demonstration of how visuospatial perception has been transformed through linguistically mediated analysis of the scene. People without the propensity of using logical concepts in the linguistic domain struggle to find figures embedded in the larger scene (not being slower at it, but being unable to) because they lack the (linguistic) means to make the scene more manageable by analytically breaking it apart.

Proponents of the 4th position — that linguistic representation constantly modulate ongoing perceptual processing — probably have no fundamental issue with the previous proposition, though they might have their reservations regarding some categories/concepts used and might prefer a description centered around attentional control. The linguistic concepts help to increase the salience of certain aspects of the stimulus, thus lowering the effect of distracting/overwhelming ones. I suspect some

difficulty stating what exactly is it about abstract concepts, as opposed to concrete ones, that especially facilitate this in this context, but overall, the claim would probably be similar: what one needs to emphasize in this context is rather abstract, so one needs (experience with) abstract concepts to do so. The proponents of the 3rd view (that language provides the mental "tools") and the 2nd (that language structures the environment which we learn to adapt to) might argue similarly. As mentioned before, the viewpoints mostly do not contradict each other.

That said, I think proponents of the 4th position would be more likely to experiment with verbal interference to affect the performance, and proponents of the 2nd and 3rd one to seek out linguistically/culturally distinct subgroups (including children) for contrast. There is no contradiction here, but there is a striking difference in focus: *structural type* of concepts, versus demonstrably direct *participation* of linguistic concepts versus *content* of concepts/experience. Importantly though, it seems to me that the theoretical position adopted here can more readily incorporate the other ones than *vice versa*. That is to say, I think the 2nd, 3rd, and 4th position would struggle explicating the effects related to abstract versus concrete concepts, while the 5th position does not have these difficulties with cross-cultural, developmental, nor "online" effects.

As for position 1 — language does not play any fundamental role in (nonlinguistic) cognition — the proponents would probably argue that we have not demonstrated that nonlinguistic thinking has been shaped by language (only that language might be involved in some way), and as such the results are not particularly profound. As discussed before in the "Comparison to other views" section, from current perspective, their expectation of *language-independent thinking* and *thinking-independent language* "modules" is unjustified. As such, there really is little common ground: one finds the fact that something cannot be achieved cognitively without the participation of language mostly irrelevant for the "language and mind" debate, the other finds the fundamental assumptions of first unfounded to begin with.

Delving into the latter more specifically, one of the issues analyzed as part of the theoretical study of the thesis (Tammik, 2014) — mixing the apparent ("phenotypical") with the inherent ("genotypical") — is possibly behind this clash of assumptions. The distinction between our linguistic and nonlinguistic processing is so apparent in our personal experience — as well as statistically dissociable in cognitive test batteries to an extent — that is tempting to give these phenomena existence and explanatory power in their own right. What follows is correlating and contrasting situations where language appears to be involved versus not, and trying to establish regularities between these. Doing this we have completely lost sight that it was the nature of these phenomena in their interaction that we set out to unravel in the first place: not how one influences the other but what they are, i.e., what is language (psychologically) and how does it relate to thinking before it. In other words, instead of looking for substantive theory about the nature of the phenomena, we are looking for statistical regularities between the apparent manifestations and using these to explain them. We are thus confusing the explanation (explanans) with

what needs to be explained (explanandum). However, putting in some definitions, it might turn out that the question of what influences what simply does not make much sense in this case. To use an old analogy (e.g., Koffka, 1935, p. 57), analyzing how hydrogen influences oxygen is not an especially good approach for understanding water; it is the structural composition and resulting emergent properties (together with the properties of the elements that make this composition possible) that one needs to analyze.

Another question, that proponents of the 1st position seem especially likely to raise, relates to confounds. Confounds themselves differ by the amount of theoretical investment needed, however. On the one hand, we have constructs like "working memory", which are very theory-laden. On the other hand, we have less controversial statistical relationships, such as better educated people having — on average — better health. I have little to say here about the first kind: constructs such as "working memory" require a thorough theoretical analysis in their own right, as well as in relation to structure of word meanings, to contribute anything to the discussion and this is outside the scope of this thesis. As for statistical confounds related to experience with abstract concepts, this is a real issue: for example, experience with abstract concepts is often acquired through formal education that is in turn, related to predictably different life experiences and better health. More specifically, it could be that experience gained from formal education drives both the propensity to think in abstract concepts, as well as their performance in visual tasks. Likewise, it could be that the "cognitive reserve" observed in Study III is not due to abstract concepts, but something else they are correlated with. Unfortunately, dealing with many of these issues is usually not feasible, if not impossible.[17] Some, however, could be addressed to an extent in subsequent studies, for example, by trying to take into account the relevant life experience related to the specific task domains and recording objective health measures related to aging. To an extent, I suspect, this issue will always remain, however.

All in all, what should we conclude from this: what do the results say about the question of "language and mind" in general and Vygotskian theory, as elaborated by Toomela, in particular? First, as already mentioned, it adds to the growing body of results demonstrating interactions between visual and linguistic processing, thus challenging the positions that draw strong distinction between these and/or claim secondary or limited role for language in cognition. As for the different views regarding the role language plays specifically, the results offer limited evidence for preferring one over the other. Although, as said, there is no inherent conflict between the views and thus no reason to support one at the expense of the other(s). The current theoretical framework drawn upon, however, seems significantly more

[17] For example, having access to certain concepts necessarily implies choices unavailable otherwise and restricting these would often be unethical. Totally restricting any (overt) behavior based on those concepts would not create a situation equal to not having them in the first place, however.

comprehensive and thus more suitable for integrating others — and beyond — rather than *vice versa*.

By "beyond", I mean that the posited theoretical framework allows for some reconceptualization and unification of — as well as cross-pollination with — previous research from fields outside the "language and mind" tradition. The most obvious candidates for this would be theories that were developed based on empirical studies employing similar cognitive tasks to the ones used here. For example, the theory of field dependence-independence (Witkin, Moore, Goodenough, & Cox, 1977) and its developments that used to be quite popular in educational psychology. This theoretical tradition resulted in a large body of empirical findings using (among other tasks) the embedded figures test similar to the ones used here.[18] Similarly, verbal tasks akin to those in this study are used in intelligence and neuropsychological test batteries (e.g., the Similarities subtest in Wechsler's intelligence scales). However, these research traditions, in my opinion, usually lack substantial theoretical conceptualization of what it really is that is being assessed. Instead they essentially just label some empirical phenomena exemplifying the "generalizations based on the statistical analysis" issue mentioned above and explored in Study I (Tammik, 2014).[19] The psycholinguistic theory championed here, could provide a general framework for (re)conceptualizing these effects and connecting them to others. So, instead of "latent variables" like cognitive styles or dimensions of intelligence, whose main justification relies in dubious statistics (Borsboom, Mellenbergh, & van Heerden, 2003), we can analyze these phenomena based on a *biologically feasible* theory of representations together with their developmental and cultural origin.

From "language and mind" research, I see most potential for fruitful cross-pollination with the (neuro)cognitive tradition (e.g., Lupyan et al.). This tradition is brilliant in modeling and experimentally unraveling the mechanisms of ongoing cognitive processes, but could be further extended into developmental and cultural domains. This in turn would benefit from a high-level coordinating framework that the cultural-historical approach as further developed by Toomela could provide. Likewise, the psycholinguistic theory championed here could benefit from better integration with modern neurocognitive work to explicate the specific cognitive and neural process involved.

All this of course, is quite speculative and warrants further study in several directions. First, the discussed reconceptualization and unification of previous work requires a significant amount of theoretical specification as well as empirical work. Second, here we only established the general association and further work could focus on the

[18] Witkin himself also noted the connection to Vygotsky's work early on (Witkin, 1950, p. 13).

[19] It is clear if you try to use these theories to actually explain something. For example: "Why am I so bad at finding hidden figures?". The answer would essentially be that I have low visuospatial intelligence or have a field-dependent cognitive style. Ok, and how do we know this is the reason? Well, because I am bad at finding hidden figures (and people cluster together on the group level based on what they are good or bad at). For a serious treatment of the problems with these kinds of theories, see Borsboom, Mellenbergh, & van Heerden (2003).

details. For example, by explicitly looking at the strategies used in visual tasks (e.g., Pennings, 1988), the specifics of the linguistic categorization performance (e.g., Giovannetti, et al., 2001), and by studying correlations with abstract knowledge in particular areas (such as geometry) in otherwise similarly educated people to gauge the specificity of the representations involved20. Third, microgenetic studies and constructive experiments21 would allow to more confidently establish the causal nature of the relationship and surface the intricacies involved. Lastly, there is (theoretically) nothing special about visuospatial perception in relation to concept development and it was only selected in this study due to the distinction often drawn in relation to verbal reasoning. Further studies should explore this in other senses, such as auditory or tactile perception, to confirm the posited generality of the transformative effect as well as to establish the domain-specific aspects of it.

[20] This would serve a different purpose compared to interference or priming studies, because it embarks from the assumption that the abstract representations have transformed the lower-level ones, which is likely to take time and does not necessarily recruit the high-level ones online once mature (although it definitely should during an intermediary stage in development). For example, a medical doctor likely looks at people slightly differently compared to lay people without constantly activating all the medical knowledge potentially relevant.

[21] Microgenetic studies, refers to detailed studies of a process unfolding, whilst constructive experiments refers to artificially recreating a process based on a theory; these often (used to) go hand in hand (Wagoner, 2009).

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REGULAR ARTICLE

Appraisal of Research Depends Upon its Conceptualization

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Abstract Smedslund and Ross (2014) have offered us an interesting opinion article concerning the usefulness of empirical research for psychological practice. Appraisal of research is obviously contingent upon the way it is conceptualized and although the authors are involved with rather different kinds of practical problems they nevertheless conceptualize research in exactly the same way. This entails a possible mismatch between questions asked and methods used to answer them. I will try to add to the discussion by examining more closely how the authors conceptualize research and discuss the problems of mismatch between questions, methods, methodology, and epistemology. I claim that the authors' view of research misses some important aspects of scientific reasoning and follows an unjustified epistemological position. Part of the arising controversy is a rather natural consequence of this but could be overcome by reconsidering the aims of science and getting epistemology, methodology and questions in line. Although I focus on the specific article and the authors' positions, I hold that the issues discussed are common and general.

Keywords Science · Epistemology · Methodology · Research vs Practice · Aristotelian vs Galileian

Smedslund and Ross (2014) have offered us an interesting opinion article concerning an important and reoccurring question about the usefulness of empirical research for psychological practice. The appraisal of research is obviously contingent upon the way it is conceptualized and conducted and the nature of the problems it is used to address. I will therefore try to add to the discussion by examining more closely how the authors conceptualize research, how it corresponds to the practical problems they face, and whether there are alternative ways that would perhaps receive a different appraisal. I come to the conclusion that the authors' view of research misses some important aspects of scientific reasoning and part of the arising controversy is a rather natural consequence of this. Fortunately it can also be overcome by turning attention to these

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issues and a shift in the underlying epistemology and conceptualization of science. Although I focus on the specific article and the authors' positions, I hold that the problems discussed are common and general.

Let me begin by drawing the reader's attention to a peculiar aspect of the opinion article. The practical problems faced by the two authors are quite different: clinical practice with individuals in the case of JS, research on biases in inference, judgment, and decision-making, and its application to public policy and real-world conflict resolution in the case of LR. Interestingly, they nevertheless conceptualize research in exactly the same way – establishing average relationships between attributes and conditions on the level of groups. This is clear from the examples given as well as from statements like "[psychological research] necessarily provides not specific laws and formulae but generalizations based on the statistical analysis that consider mean tendencies and statistical significance of observed differences and associations" (emphasis mine).

This approach to research can be generally summarized as a recipe: "To conduct a study, think of a hypothesis; assume the truth of the hypothesis and derive from it a prediction about how behavior on some cognitive task will differ if the task is presented in this way or that way; collect the relevant data and run a statistical significance test to verify that the observed difference between the two experimental conditions is real. If the observed difference is statistically significant, publish; if not, run another experiment." (Ohlsson, 2010, pp. 28–29). Or more bluntly: "(1) set up a statistical null hypothesis, but do not specify your own hypothesis nor any alternative hypothesis, (2) use the 5 % significance level for rejecting the null and accepting your hypothesis, and (3) always perform this procedure" (Gigerenzer, 2004).

This is a very common way to conceptualize and carry out research in psychology and it is firmly maintained by the research and higher educational community (Gigerenzer, 1993; 2004; Ohlsson, 2010). The problem, however, is that this approach is obviously unjustified, absent in developed sciences, and in general rather unscientific—position which has been well articulated again and again (e.g., Gigerenzer, 1993; 2004; Lewin, 1931; Meehl, 1978; 1997; Ohlsson, 2010; Strong 1991; see also Toomela, 2010a, 2010b). The crucial reminder from Smedslund and Ross that it is impossible to offer formulae or algorithms that can be used mindlessly for dealing with practical problems applies as strongly to research problems as well. Science or research is not about following a recipe but a special way of thinking and answering questions—i.e., creating (a special type of) knowledge.[1] Research therefore starts with a question (or a problem) and the approach to answering a question has to be suited to that question. It is a natural consequence of the recipe book conceptualization of research that research questions are tailored for the (statistical) methods not the other way around (as it should be)—a far too common sight in psychology (Gigerenzer, 1993; Ohlsson, 2010; Toomela, 2010b).

In the context of the article of Smedslund and Ross (2014), it is not obvious that the same approach to research should be applicable to problems as diverse as the ones that the authors are involved with. It at least calls for an explicit analysis because the usefulness of a methodological approach can only be discussed in relation to the (type

[1] Although the exact criteria for science (and scientific knowledge) are controversial, the claim itself – that it is a special way of creating knowledge – is not.

of) questions it is used to address—it is not justified to expect an approach suited for one type of questions to be automatically applicable for every other. In other words, one should design research in accordance with the questions one aims to answer. If Ross is involved with recommending an intervention to address a social issue, then he needs to know which of the possible options work the best; with best meaning the one that alleviates the problem in a group to the largest extent (according to some criteria) or at least be sure that the intervention he recommends actually works better than doing nothing. That means that in general the (Fisherian) null hypothesis testing approach makes sense. If Smedslund is involved with solving in some sense unique problems of individuals then findings from this kind of research seem to be of a more limited value exactly as he claims (see also Smedslund, 2009); nor should they be expected to be of much use for theory building—it is a clear characteristic of Fisherian approach that it should be used when one does not know much about the problem at hand (Gigerenzer, 2004). This approach is meant exactly for the kind of complex "on average" practical problems that Ross describes but not for the kind of problems that Smedslund deals with. There thus seems to be a mismatch between questions and methodology resulting from equating one methodological approach with research as such.

To overcome and/or avoid this mismatch it is of utmost importance to first make the questions explicit and analyze what kind of questions one is dealing with so it would be possible to decide upon the appropriate approach(es) to answering them. A question about the magnitude or usefulness of a specific intervention in a specific context is different from a question whether a posited theory is "true" which is again different from a question of how to explain an interesting or unexpected observation; question about prediction is different from question about explanation and explanations themselves are of different kind (e.g., reasons are different from causes). These are all different from metatheoretical questions about mind (and the how to study it) and questions about questions (e.g., which questions are worth asking/answering). And so on. This is not the place to dissect this complex issue but what matters is that all of these different questions also require different approaches to tackle them—whereas the typical social science approach to research might be appropriate for some practical purposes it is usually not appropriate for many other types of questions and theory building (Gigerenzer, 1993; 2004; Meehl, 1978; 1997; Ohlsson, 2010; Toomela, 2010b; see also Toomela, 2007).[2] Fortunately it is not the case that psychological

[2] There are also other fundamental reasons for making questions explicit. First, without doing so it is not possible in principle to know whether a question got answered. If I do not know what I want to know, how do I know that I attained the knowledge? The only answer seems to be that I have to rely on some kind of feeling. I think that this is a very bad criterion of knowledge in any case but it is definitely not acceptable if the endeavor concerns someone else beside the individual researcher engaging in it and science obviously does! The space limitations do not allow me to go further into the issue but it is not as trivial as it might seem to some because there are researchers (usually following some of the qualitative approaches) who actively argue against having research questions and actually do endorse relying on feelings in scientific practice. For a thorough analysis and criticism of these and other problems see Toomela (2011).

Second, some questions are better than others and not all questions are meaningful. "The development of science is not determined so much by answering questions in increasingly exact ways; the development of science is determined by asking the right questions. Already Vygotsky (1982), following Münsterberg, suggested that it is much more meaningful to answer the right question even approximately than to answer the wrong question exactly." (Toomela, 2010a, p. 9). So the questions need to be made explicit and analyzed in a general theoretical/epistemological framework to judge their relative importance and whether they are worth answering at all.

research necessarily has to deal with "generalizations based on the statistical analysis that consider mean tendencies and statistical significance of observed differences and associations". Unfortunately such a position itself seems to stem from a more fundamental epistemological issue.

To discuss this it is first useful to distinguish methodology from epistemology and methods from methodology (e.g., Carter & Little, 2007). The aim of epistemology is to provide a theory of what it means to know something (i.e., justifying knowledge); the aim of methodology is to provide guidelines for the acquisition of knowledge (i.e., justifying methods); by methods I mean just the specific procedures for collecting or manipulating data, e.g., analysis of variance. These are obviously closely related but hierarchically so. Ideally they should form a unified whole where methodology is derived from epistemology and methods developed based on methodology and so the problems on the more general level have a larger impact on the less general level than vice versa. In reality they often become divorced from or unduly mixed with each other and this is felt in the current discussion as well. I think that the discussed conceptualization of research is partly a result of a confusion between these and partly a result of an outdated epistemology—especially understanding of "laws"—attributed to science. Above I focused on the issue of equating science/research with a methodological approach which results in an overly rigid understanding (and premature criticism) of the former. Next I will discuss the issue of an epistemology that often (implicitly) justifies this methodological choice by assigning to science a goal that does not actually fit its more developed branches.

In the authors' epistemological positions (presented in the sections "Scientific Knowledge and Practice in Psychology versus the Natural Sciences" and "Conclusions") note the following (related) characteristics: (1) the conceptualization of laws as invariant relationships between observed events, (2) focus on knowledge from generalization with (3) apparent similarity between the situations/samples being the criteria for generalizing from one to the other (e.g., the experimental setting or sample has to conform to the application setting or sample). In short, their position seems to be that science is about establishing empirical regularities in the world (and organizing those in theories).

Smedslund has previously stated this explicitly: "Mainstream researchers attempt to assemble a fourth type of knowledge, namely empirically based laws or regularities" (Smedslund, 2009, p. 779). By empirical laws he means "relations of the type if A then always (or with a certain probability) B" (Smedslund, 2009, p. 784, emphasis original). He then goes on to list (four) characteristics of the mind that make establishing such laws in psychology impossible. So why was Meehl, listing 20 problematic aspects for psychological research (also covering those listed by Smedslund) less pessimistic (Meehl, 1978)? It is because (developed) science is not about establishing empirical laws! This is not an issue of psychology, it does not make sense for any (theoretical) science (Ohlsson, 2010) and is only useful for some practical applications before an adequate theory is available (Toomela, 2010b). What any (theoretical) science—psychology included—should be interested in are not empirical laws but causal theories (Meehl, 1978; 1997). Causal theories are different from empirical laws for latter can be derived from former but not vice versa—it is the crucial difference between the explanans and explanandum.

Empirical as well as common sense or a priori "laws" are what need to be explained by a scientific theory not just established. In the words of Kurt Koffka (1935): "A science, therefore, gains in value and significance not by the number of individual facts it collects but by the generality and power of its theories, a conclusion which is the very opposite of the statement from which our discussion started. Such a view, however, does not look down upon facts, for theories are theories of facts and can be tested only by facts, they are not idle speculations of what might be, but theoriai, i.e., surveys, intuitions, of what is."

It should also be kept in mind that facts are not all of the same status and it is precisely the theories that give the facts their significance. Staying with Koffka (1935): "It is a "fact" that heavy bodies fall more quickly than light ones, as anyone can test by dropping a pencil and a sheet of paper. But it is a complex, not a simple fact, whereas the simple fact is that all bodies fall with the same velocity in a vacuum. From this scientific fact the everyday fact can be derived but not vice versa."

It is the conflict between "Aristotelian" and "Galileian" modes of thought (or epistemology) addressed by Lewin (1931) in his classic paper with the former being characterized by just the features found in the epistemological position of Smedslund and Ross (see also Strong (1991) for the same argument as presented here). For the sake of brevity I will not repeat here all the characteristics of "Aristotelian" science but I urge the reader to (re) visit the paper (and/or see that of Strong). I will just bring an example to illustrate the point that for "Aristotelian" science laws are based on regularity in concretely observable cases ("phenotypes") while for "Galileian" science laws are based on their underlying dynamics ("genotypes").

"The law of falling bodies, for example, does not assert that bodies very frequently fall downward. It does not assert that the event to which the formula, $s = {}^{1}/_{2}gt^{2}$, applies, the "free and unimpeded fall" of a body, occurs regularly or even frequently in the actual history of the world. Whether the event described by the law occurs rarely or often has nothing to do with the law. Indeed, in a certain sense, the law refers only to cases that are never realized, or only approximately realized, in the actual course of events. Only in experiment, that is, under artificially constructed conditions, do cases occur which approximate the event with which the law is concerned. The propositions of modern physics, which are often considered to be "anti—speculative" and "empirical," unquestionably have in comparison with Aristotelian empiricism a much less empirical, a much more constructive character than the Aristotelian concepts based immediately upon historic actuality." (Lewin, 1931, p. 150).

"The general validity, for example, of the law of movement on an inclined plane is not established by taking the average of as many cases as possible of real stones actually rolling down hills, and then considering this average as the most probable case. It is based rather upon the "frictionless" rolling of an "ideal" sphere down an "absolutely straight" and hard plane, that is, upon a process that even the laboratory can only approximate, and which is most extremely improbable in daily life." (Lewin, 1931, p. 161).

It is important to realize that such theoretical claims are not created through generalization but rather through abstraction; the abstractions drive the generalizations not the other way around (Ohlsson & Lehtinen, 1997). So it is not the case that chemistry's advances stem from the fact that they could collect pure elements and examine their properties and generalize from those; on the contrary it is the theoretical

abstractions that got them to the point where they could claim that pure elements in fact exist and can be sampled in the first place. A "pure element" is what it is precisely through a sophisticated theory of particles and their interactions and what makes something observable a pure element is anything but obvious. It is the theory that shows the similarity in apparently dissimilar and distinguishes nonessential—phenotypical—facts from the essential—genotypical—ones (e.g., despite the different properties of these substances they all consist of only one type of atoms). The laws that are stable and invariant are theoretical principles rather than empirical observations (for natural sciences as well). This is also the reason why the apparent similarity of the experimental and application setting is essentially irrelevant: generalization comes from the abstraction, it is the genotypical similarity that matters not the phenotypical one.[3] The artificiality of the experimental setting is just a byproduct of creating a situation most suitable for testing (but not necessarily coming up with) the theoretical assertions. The "Galileian" view transcends the antithesis between the unique and the general (the unique being a specific manifestation of the general principles) and avoids the "dilemma" that forces the "Aristotelian" scientist to resort to "empirical generalizations" (i.e. "on average" claims). Latter only makes sense when no theoretical understanding is available and this is exactly what "Galileian" science aims to overcome.

As mentioned above, an issue on a more fundamental level (epistemology) has more devastating consequences to higher levels (methodology and methods) than vice versa. Methods can be improved if their shortcoming are specified and if a methodological approach is unfitting to an interesting question, another ones can be chosen or developed. But if the epistemological position leaves one to think that statistical regularities in observations are the best we can get from (empirical) research then science is deemed unhelpful in a situation where it has actually shown its power most strikingly—bringing order to the seemingly uncertain, fleeting, and chaotic in our everyday lives.

This "Aristotelian" conceptualization of science is probably what is underlying Smedslund's pessimistic attitude towards psychological research (e.g., Smedslund, 2009) and partly the reason why his own answer to the problem of creating a (practically relevant) systematic body of knowledge for psychology—his psychologic—only defines the concepts in terms of reasons instead of causes (reasons exist for a person, causes exist independently of any person—e.g., a feeling may be a reason for my action but there are causes for feelings irrespective of me) (Smedslund, 2011). I agree that it is important to make the distinction but the whole issue of causes in psychology is a lot less problematic when looked at from "Galileian" perspective that does not aim to just generalize from observed regularities.

Furthermore, Smedslund's philosophical argument for reasons instead of causes does not hold and again shows an overly rigid view of science. He states that the alternative to his approach would be "the so—called operational definitions, linking concepts to fixed sets of behavioral or physiological conditions" (Smedslund, 2011, p. 127). This position probably comes from unduly admixing operation(al)ism with the epistemological positions of early logical positivism and not making clear distinctions between definitions in science and logics and between epistemology and methodology

[3] The adequacy of the theoretical claims is of course a matter of empirical research and testing the assertions in diverse situations and samples is obviously necessary. What counts as diverse is, however, again determined by the theory.

(Feest, 2005). In philosophy of science this kind of strong operation(al)ism was quickly revised (largely by the same people who created it) and in psychology not actually held by many accused of it; the issues are actually elsewhere (Feest, 2005; Meehl, 1993).[4]

In short, I believe the reason behind Smedslund's frustration with empirical research lies in the current research practices in psychology that he prematurely takes as inevitable and is exacerbated by the imperative of being "evidence-based" in his work which means using the for him useless results of this research. These practices, however, are usually just conventional and result from poor metatheoretic thinking that actually mostly misses the real essence of scientific investigation. What Smedslund's pessimism applies to is not science proper but rather an outdated epistemology (Lewin, 1931) or a mindless ritual (Gigerenzer, 2004). I do agree with him, however, that a large part of research in psychology is actually pseudoempirical—i.e., empirically "testing" what is logically implied—and consists of reducing self-imposed artificial uncertainty (Smedslund, 1991). I also could not agree more that psychology needs to define its concepts and develop an explicit conceptual system to make what we (think we) already know clear. It is a truism in philosophy that we do not really know what we know. Making our assumptions and implicit knowledge explicit is the only way to avoid pseudoempirical and unproductive research. For this reason alone the work of Smedslund on psycho-logic should be highly appreciated!

Furthermore, I agree with him that current research practices in psychology are mostly inadequate for understanding the mind (e.g., Smedslund, 2009). The reason, most generally, is that research has to be conducted on the same level of analysis as the phenomena we are interested in and since mind is an attribute of the individual it needs to be studied on the level of individuals and not groups of individuals. A direct inference from latter to former is simply unjustified (Borsboom et al. 2003; Molenaar, 2004); "if one wants to know what happens in a person, one must study that person." (Borsboom et al., 2003, p. 216). Luckily, although the group level approaches are clearly dominant in psychological research, there are alternative methodological approaches available. In addition to the qualitative or hermeneutic approaches that Smedslund seems to favor, there is also an active development of so-called person-oriented approaches that have specifically taken up the issue of developing quantitative methods to analyze data on the level of individuals (Bergman & Trost, 2006; von Eye & Bogat, 2006; see also Molenaar, 2004; Molenaar & Campbell, 2009). Some of these approaches, by the way, stem from exactly the kind of view of the mind (as unique dynamic open system) that Smedslund adheres to (Bergman & Magnusson, 1997; Bergman et al. 2003; Bergman & Trost, 2006).

I want to reemphasize, though, that the methodological practices I have criticized do have their uses and are perfectly suitable for some situations and research questions, including the type of problems faced by Ross and illustrated nicely in the examples

[4] The alternative (actually in use by most scientists [and not just in psychology]) is open concepts (Pap, 2006) which are perfectly fine but require some caution towards them. As Meehl (1978) put it already years ago: "the unavoidability of open concepts in social and biological science tempts us to sidestep it by fake operationism on the one side (if we are of the tough-minded, superscientific orientation) or to be contented with fuzzy verbalisms on the other side (if we are more artsy-craftsy or literary), thinking that it is the best we can get. The important point for methodology of psychology is that just as in statistics one can have a reasonably precise theory of probable inference, being "quasi-exact about the inherently inexact," so psychologists should learn to be sophisticated and rigorous in their metathinking about open concepts at the substantive level."

given by the authors. Although these examples clearly demonstrate the usefulness of empirical research in psychology, the profound advances of older fields of science come from a mindset quite different from the one that usually underlies research of the kind described. As with psychological practice, research too involves addressing specific issues and this can only work when methods are based on sound methodological considerations in concordance with the type of questions one is dealing with. The latter eventually receive their justification (either explicitly or implicitly) from epistemology, that is, from the specification of the characteristics of the knowledge we are ultimately trying to achieve. In psychology there is often an evident mismatch between questions, methods, methodology, and epistemology creating false controversies and making genuine advances seem almost impossible. However, before settling for "on average" theories (which are usually little more than just labeling the research findings) or giving up on scientific endeavor in general we should try to get the underlying issues straight, i.e., our epistemology, methodology and questions in line. I believe psychology could be an extremely useful (albeit challenging) science but only as the "Galileian" not the "Aristotelian" kind.

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II

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Relationships between visual figure discrimination, verbal abilities, and gender

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Abstract. This study investigated the relationships between verbal thinking and performance on visual figure discrimination tasks from a Vygotskian perspective in a large varied adult sample ($N = 428$). A test designed to assess the structure of word meanings (ie tendency to think in 'everyday' or 'scientific' concepts as distinguished by Vygotsky) together with two contour picture tasks was presented. Visual tasks were a modified version of Poppelreuter's overlapping figures and a picture depicting a meaningful scene. On both tasks concrete objects and abstract meaningless shapes had to be identified. In addition to relationships between visual task performance and word meaning structure, the effects of the meaningful scene and relations with gender were examined. The results confirmed the expected relation between word meaning structure and visual performance. Furthermore, they suggested a specific effect of the meaningful whole and a male advantage, especially for the first task in which women seemed to benefit less from advanced word meaning structure.

Keywords: embedded figures, visual search, figure–ground discrimination, Vygotsky, word meaning structure, language, gender

1 Introduction

One of the classical ways to assess visual abilities involves tasks where different contour drawings are either overlapping or embedded (hidden) in one another requiring so-called figure–ground discrimination to recognise (find) them. The first type of these tasks can be traced back to the works of Poppelreuter (1917) and the latter one to the works of Gottschaldt (1926). Both are still used and studied today. The main difference between the tasks is that in the overlapping figures the contours are intersecting, whereas in the embedded figures the contours are shared (so that the contours making up a simpler figure form part of a complex one). Of these two tasks, the embedded (hidden) figures is clearly the more demanding one (Ghent 1956).

Interestingly, most research using embedded figures has not investigated visual ability but cognitive styles—more specifically, field dependence–independence (Witkin et al 1977). Field dependence–independence refers to the extent to which individuals tend to perceive the surrounding (perceptual) field as a whole, so that the organisation of the field has a strong influence on their perception (field dependent); or analytically, seeing parts of the field as more separate from each other, enabling them to (re)organise the field according to their needs (field independent). The embedded figures test was used as one measure of field dependence–independence because it requires active restructuring of the visual field to overcome the organisation imposed by the complex figure.

Although this cognitive-style view of embedded figures performance has been repeatedly challenged (McKenna 1984; Miyake et al 2001; Rittschof 2010), the field dependence–independence tradition gave rise to an enormous amount of research related to the task. A portion of the findings accumulated over the years perhaps surprisingly suggests that the ability to solve the embedded figures is also related to some verbal abstraction abilities. Lefever and Ehri (1976), for example, found a relationship with the ability to identify multiple meanings from ambiguous sentences, and Longoni and Pizzamiglio (1981) found a

relation with a task that required the formation of a new group from semantically grouped words based on their alternative meanings, but not with any other of the 6 verbal tasks used in their study.

Bialystok (1992) demonstrated that the performance on embedded figures was related to metalinguistic awareness in elementary school pupils. She presented the children with two tasks requiring grammaticality judgments in either semantically meaningful or nonsense sentences and matching a stimulus word with an either semantically or phonetically similar word. It was found that the score for the embedded figures task was related to the score for the first metalinguistic awareness task only in the grammatically correct but semantically meaningless condition—that is, children who got lower scores for the embedded figures task were also more disturbed by the silliness of the content of the sentences. There was also a relationship with the second task. Bialystok interpreted her results from an attentional control perspective.

Dickstein (1968) used a concept attainment task, presenting participants with 81 cards that differed from each other in 4 respects (3 different possibilities for each). Participants were given one card and asked to select from the set another one that represented the same category. After each choice they received feedback on whether the choice was correct or not. This process lasted until the participant was able to state the rule underlying the category (eg 3 borders and two figures). As expected, field-independent participants performed better on all aspects of the performance measured (*n* choices to solution, *n* incorrect verbalisations, *n* unvaried attributes, and *n* attributes changed on initial choice). A relationship between field independence and concept formation (participants had to guess the rule after 3 examples) has also been found by Elkind et al (1963).

The method used by Dickstein is very similar to the one used by Vygotsky (1934/1986) in his classical studies and borrowed by Hanfmann (1941) to conduct studies on thinking. In her study Hanfmann distinguished between two types of approaches to solving the task—perceptual and conceptual. The 'conceptual' group approached the task analytically by formulating (explicit) hypotheses and then trying them out one by one until the solution was found. The 'perceptual' group, on the other hand, kept in close contact with the task material, manipulating and grouping it until it 'looked right', sometimes achieving the correct categorisation before being able to state the underlying rule. The similarity between different performances on the Vygotsky test and the embedded figures was actually noticed by Witkin (1950) early on; and a correlation between the scores on the two tasks has indeed been reported, although in a clinical sample (Rehermann and Brun 1978).

Vygotsky (1934/1986) himself used the test for a slightly different purpose—understanding the development of linguistic representations. The main idea driving his research was that, in the human mind, mental processes are not 'direct' but *mediated* by symbols (usually words) (Vygotsky and Luria 1994). What this means is that, during development, children learn to use symbols as *tools* to guide their so-called 'natural' mental processes—symbols intervene in the formerly automatic processing and start to mediate it. In other words, with the emergence of semiotically mediated mental operations, the same problems are solved in novel ways; perceptual information is processed also verbally. In the realm of perception, for example, words may support analysis of a perceptual field into 'nonnatural' elements, such as a contour or segment of it distinguished from all other properties of perceived objects and synthesis of these distinguished elements in novel ways. Vygotsky expressed these ideas as follows:

> "From the first steps of the child's development, the word intrudes into the child's perception, singling out separate elements overcoming the natural structure of the sensory field and, as it were, forming new (artificially introduced and mobile) structural centres" (Vygotsky and Luria 1994, page 125).

Another noteworthy idea in Vygotsky's theory is that semiotic 'tools', the psychological structure of symbols, change during the course of development. The development of the regulatory function of symbols is a long process and goes hand in hand with the development of symbols themselves, giving rise to concepts with different types of meaning structures. The different kinds of concepts, in turn, underlie different kinds of mental processes [Gredler 2009; Vygotsky 1934/1986; see also Toomela (2003a) for an elaboration of the theory].

Vygotsky (1934/1986) distinguished several types of symbol meaning structures; two of them are relevant here, the so-called 'everyday' and 'scientific' concepts. Everyday concepts are formed based on everyday experience with the words and their use. They are essentially bundles of exemplars and related experiences. As such, they do not contain metalinguistic information, making their boundaries fuzzy and implicit (ie the underlying reasons and principles for categorisation are not consciously accessible to the user). The meaning of a word in this stage is *concrete* and *factual*.

The scientific concepts, on the other hand, are *abstract* and *logical*. They are related to formal education and form the basis of everyday concepts as superordinate categories—that is, symbols for categorising other symbols. They are essentially definitions that categorise concepts into logical hierarchies. As such, they contain metalinguistic knowledge that makes their boundaries and interrelations (more or less) clear and explicit to the user. However, note that scientific concepts are not concepts from science, although most concepts from science are scientific concepts. What is essential is the structure, not the content, of the concept.

The possible relation between the structure of word meanings (thinking in everyday and scientific concepts) with the ability to disembed complex visual stimuli relies on the characteristics of the respective representations and thinking predominated by one or the other. Thinking in everyday concepts is not guided by explicit abstract rules but rather by subjective impressions derived from concrete (perceptual) experience. Thinking in scientific concepts, on the other hand, is based on abstract rules somewhat distanced from the concrete material upon which they are imposed, making it easier to guide ones attention to a specific property of the visual stimuli while disregarding the rest with an aim to find the figures. The types of thinking correspond well to the notions of Hanfmann (1941) and observations of Witkin and colleagues in relation to field dependence–independence (Witkin 1950; Witkin et al 1977).

The results of Stasz et al (1976), who assessed the structure of concepts (attained in a social studies minicourse) directly and related it to field dependence–independence (which unfortunately for the present study was assessed using other measures along with embedded figures), are consistent with present claims. Namely, Stasz et al found that the field-independent subjects (those better at embedded figures and similar tasks) exhibited a structure of concepts that was more differentiated and closer to the logical model intended.

The above-cited studies that reported relations between field independence and verbal abstraction abilities can also be understood from the current perspective, as they too demanded overcoming a subjective (first) impression by the subjects to either find alternative meanings (Lefever and Ehri 1976; Longoni and Pizzamiglio 1981) or ignore the semantic absurdity in grammaticality judgments (Bialystok 1992), all depending on the ability to operate with the linguistic system abstractly. This ability should develop together with 'metalinguistic' scientific concepts, which should theoretically also be related to disembedding ability.

The results of Bialystok (1992) described above additionally draw attention to another interesting theme. Namely, they suggest that the meaningfulness of the whole (sentences, in her study) could be another factor that interferes with the abstract analysis of the stimuli. It would therefore be interesting to examine whether meaningfulness of the scene from which figures have to be disembedded would also affect the participants' ability to do so.

Coming back to the types of thinking proposed above, it would be expected that people thinking mainly in everyday concepts would be more disturbed by the meaningfulness of the scene when needed to 'break it up' in order to find the hidden figures.

Accordingly, we formed the following hypotheses. First, (1) we expect that healthy people would not find it difficult to recognise overlapping contour drawings of concrete everyday objects. However, (2) it should be more difficult for them to find meaningless abstract shapes that violate the Gestalt principles of symmetry and of good continuation: the tendency to group elements to form smooth contours (Koffka 1935; Wagemans et al 2012). Further, although overlapping figures have been shown to be clearly easier to find compared with embedded figures (Ghent 1956), this should not hold for the type of abstract shapes mentioned; on the contrary, the intersection of many lines should make extra demands on working memory/selective attention compared with finding embedded figures when there is no such overburdening of the scene present.[(1)]

At the same time, (3) it was expected that the meaningfulness of the scene to be 'broken up' in order to locate the embedded figures would introduce a specific challenge (especially for those thinking in everyday concepts) in a way similar to that of the sentences in Bialystok's (1992) study.

Our main hypothesis was that, (4) for the reasons discussed above, the ability to overcome automatic visual processes in order to find the challenging abstract figures would be related to the word meaning structure—that is, propensity to think in scientific concepts was hypothesised to play a significant role in enabling the required analysis of the visual scenes. Therefore, we expected to find a correlation between the measure of word meaning structure and performance on figure–ground discrimination tasks.

Finally, (5) drawing on the notion of gender differences on both the Vygotsky test and the embedded figures by Witkin (1950) and the well-established male advantage on some visuospatial tasks (Voyer et al 1995), the relationships with gender were also investigated with a particular interest of whether there is any interaction between the effects of gender and word meaning structure related to visual performance.

To assess the hypotheses, we presented our participants with two contour picture tasks, one of them consisting of overlapping figures and the other constituting a meaningful scene. The participants were asked to find figures depicting concrete everyday objects as well as abstract meaningless shapes that either consisted of segments of the overlapping everyday objects or were embedded in the scene (see figures 1 and 2 for examples). In contrast to the classical embedded figures tasks, we did not use an efficacy measure (time) but only the number of correct solutions—that is, the ability of participants to solve the tasks. Our verbal measure to assess the structure of word meanings also differs from verbal measures used in previous studies on the relationships between verbal abilities and visual disembedding and does not allow for an interpretation used to account for most of the above-mentioned results—namely, that there is a general restructuring or attentional guidance ability that works in both visual as well as other domains.

Our sample was compiled so as to encompass people with a broad variation in structure of word meanings. The sample therefore consisted of people with a wide age range and different educational and occupational backgrounds.

[(1)] The fact that hidden figures test performance relies on visuospatial and executive components of Baddeley's classical model of working memory was experimentally demonstrated by Miyake et al (2001). For discussions on the relation between the concepts of working memory and attention see, for example, Gazzaley and Nobre (2012) and Postle (2006).

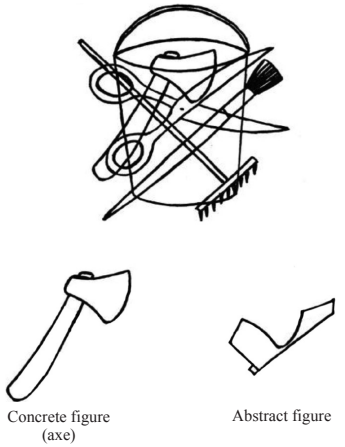

Figure 1. Contour picture of overlapping figures.

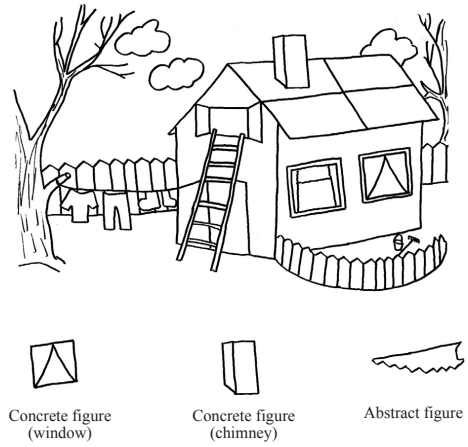

Figure 2. Contour picture of a meaningful scene.

In addition to common group-level analyses, we also analysed our data from a person-oriented approach. The reason for this was that typical group-level analyses (eg multiple regression) assume homogeneity of the sample and aggregate data over studied cases, losing the possibility to discover qualitatively different types of interrelations between the variables among different persons. The outcome is a loss of interesting information as well as possibly misleading conclusions about the phenomena under study (von Eye and Bogat 2006). The general theoretical stance underlying the person-oriented approach is that each psyche forms an organised whole actively adapting to its environment; therefore, one should focus on the patterns of characteristics (both common and uncommon) at the level of individuals rather than on only covariance between variables aggregated at a group level (Bergman and Magnusson 1997; Bergman et al 2002).

2 Method

2.1 *Participants*

The sample consisted of 428 healthy participants (200 male) with an age range of 17–69 years and a mean of 37.25 years (SD = 15 years). The sample was selected with the clear aim of involving participants with different levels of education and age; care was taken that the gender distribution in the sample would be about the same according to both age and education-level variables. Participants were recruited using various methods (eg personal contacts, advertisements). With one value missing, 163 participants had primary education (9 years or less), 149 had secondary education (12 years), and 115 had higher education (15 years or more). No statistically significant differences (assessed with the Kolmogorov–Smirnov test) were found between males and females in terms of age and years of formal education ($p > 0.5$ for both).

2.2 *Materials and procedure*

To assess visual discrimination abilities, two different contour picture tasks were used—the concrete and abstract contour tracing task (CACTT) (Toomela 2007a) and the situational embedded figure task (SEFT) (Toomela 2007b).

The CACTT was a modified version of the Poppelreuter's task (adapted from Luria 1969). The task comprised two test cards with line drawings of 5 overlapping figures of everyday objects. The overlapping figures covered 10 × 10 cm. For both test cards four line drawings on separate cards were presented one by one. On two cards the exact copy of the line drawing of one of the five objects was drawn. On the other two cards abstract contours from the same overlapping figures test card were drawn so that the figure contained segments of several of the objects on the test card (see figure 1 for an example). It was explained that the extracted figures on the separate cards were of exactly the same size and orientation as on the test card. The participants were asked to trace the contour of the single figure on the test card with his or her finger. The first single item presented was always a concrete object. There was no time constraint on finding the solution to the task. A response was coded as correct if the person traced at least 90% of the figure drawn on the separate card. In case of doubt, the person was encouraged to trace the contour as exactly as possible. The maximum number of correct answers for concrete objects and for abstract contours was four in both cases. Although the two types of figures are the same from a physics perspective, our visual system automatically recognises the 'everyday' objects and structures the visual field accordingly (they 'pop out'). Locating abstract figures thus requires overcoming these automatic processes to view the lines as belonging to the abstract figures rather than 'everyday' objects.

The SEFT comprised a 29 × 19 cm line drawing depicting a simple meaningful scene—a house with a garden. As in the CACTT, the participants were presented with two types of figures—concrete and abstract—but this time there was no overlapping of figures, arguably making fewer demands on working memory or selective attention processes (see figure 2 for an example). Instruction and coding of answers was similar to that used in the CACTT. The maximum number of correct answers for concrete objects and for abstract contours was three in both cases.

Both tasks were presented on paper with both the simple (to be found) figure and large figure visible to the participant simultaneously. All verbal labels were avoided, and the figures were referred to only as 'it'. There were no time constraints; and if the participants stated that they were not able to find the figure, they were encouraged to try again (prompts were not prespecified). Encouragement was used in order to diminish the confounding effect of low motivation. As such, it was a measure of ability to find the figure instead of efficacy of finding it. Visual tasks were presented before the word meanings structure test (WMST) (below).

The structure of word meanings or the propensity to think in either scientific-type or everyday-type concepts (as distinguished by Vygotsky) was assessed with the WMST (Toomela 2007c). This test consists of three complementary parts. In the first part the participants were asked to define 6 concepts, half of them being concrete (eg school) and half abstract (eg republic). In the second part the participants were asked to describe the similarity of 6 concept pairs, some belonging to the same category (eg cat–dog) while others are in a complementary relationship (eg horse–rider). In the last part the participants were presented with 6 triplets of words (eg carrot–soup–potato) from which they had to choose the two that 'go together' and explain why.

The answers were coded as everyday concepts (0) when the definition, similarity description, or reason for commonality was based on (a) sensory attributes (eg cat and dog are similar because both have four legs), (b) observations of everyday activities (eg school is where children go for learning), (c) observations of everyday situations (eg carrot and potato go together because they both grow in the field), (d) description of function (eg typewriter and pen are both for writing), (e) sharing of parts (eg car and bicycle go together because both have wheels), or (f) no answer (because some items are not easily answerable without scientific concepts—for example, the similarity between horse and rider).

The answers were coded as scientific concepts (1) when (a) the relationship between words were defined hierarchically (eg horse and rider go together because they are both living creatures) or (b) the word was related to hierarchically higher level concept (eg school is an educational institution). The maximum score (*n* scientific concepts) in the test was 18. In addition, the number of questions with no answer was registered separately. Theoretically, the lack of any answer represents a less-developed form of responding compared with an everyday-concept type of answers. The interrater agreement between coders has been previously reported as very high (Cohen's $\kappa = 0.91$) (Toomela 2003b).

For person-level analyses, configural frequency analysis (CFA) (von Eye et al 1996) was used. CFA is a statistical method for multivariate analysis of categorical variables, which allows us to identify patterns (configurations) that occur significantly more often (*types*) or more rarely (*antitypes*) than would be expected by chance. It is a person-oriented method because frequencies of people corresponding to possible configurations are assessed, thus avoiding the information loss related to typical variable-level analyses (eg regression analysis) that aggregate data over studied cases. CFA was implemented using the SLEIPNER 2.1 statistical package (Bergman and El-Khouri 2002).

3 Results

As a background for further analyses, it was confirmed that our sample really consisted of people with sufficiently different scores on the WMST ($M = 10.09$, SD = 3.83, range 0–18). There was no statistically significant relationship between the WMST score and gender ($t_{426} = -0.893$, $p > 0.35$). Our first three hypotheses concerned the relationships between the tasks (CACTT versus SEFT) and conditions (concrete versus abstract).

Of 428 participants, 424 (~99.1%) were able to find all concrete pictures on the CACT task, and 401 (~93.7%) found all concrete pictures on the SEFT. This difference in the distribution of nonmaximum scores was statistically significant ($\chi^2_1 = 17.065$, $p < 0.001$), although it related mostly to one particular figure on the SEFT—the chimney. Because finding concrete parts of pictures was near the ceiling level of performance, the following analyses concerned only the abstract figures.

There was a clear positive correlation between the abstract figures conditions of the two tasks ($r = 0.641$, $p < 0.001$), yet the level of performance differed between tasks, as we expected. Looking at the possible results configurations [coded as 'high' meaning maximum score, 'low' meaning 0–1 correct, and 'medium' consisting of the rest (2 correct for SEFT and 2–3 correct for CACTT)] (table 1), one can see that configurations in which people are able to solve the SEFT but not the CACTT are more common than the opposite variant (proportion of people achieving maximum scores were 51.4% and 32%, respectively; $\chi^2_1 = 19.297$, $p < 0.001$), meaning that the CACTT with abstract figures was indeed more difficult to solve.

Table 1. Performance configurations on visual tasks.

CACTT–SEFT configuration	*N*	CACTT–SEFT configuration	*N*	CACTT–SEFT configuration	*N*
Low–low	79	Medium–low	27	High–low	2
Low–medium	39	Medium–medium	42	High–medium	19
Low–high	22	Medium–high	82	High–high	116
Overall total					*428*

Note. Low = 0–1; medium = 2–3(CACTT)/2(SEFT) correct; high = maximum score;
CACTT = concrete and abstract contour tracing task; SEFT = situational embedded figure task.

The configurations where the maximum score on CACTT was combined with less than the maximum on SEFT were particularly rare (2+19 people compared with 22+82 in opposite configurations; $\chi^2_1 = 55.112$, $p < 0.001$).

It is noteworthy that there were some people [48 (~11.2%)] who got a better result on CACTT than on SEFT, suggesting that, as hypothesised, there is indeed a specific challenge brought about by the meaningfulness of the scene to be 'broken up'. Adding WMST score to the analysis did not support the expectation that this challenge would be related to word meaning structure, however.

In the next step we assessed our main hypothesis that there should be a relationship between the levels of performance on WMST and visual discrimination tasks. Performances on the tasks correlated as expected ($r = 0.330$, $p < 0.001$ for CACTT and $r = 0.365$, $p < 0.001$ for SEFT), and the number of missing answers had a specific contribution (see below).

Our last question concerned the relations with gender. A two-way mixed ANOVA (using standardised scores) revealed a significant main effect of gender ($F_{1,426} = 6.116$, $p < 0.015$, Cohen's $d = 0.217$) on visual performance in the two tasks and a task × gender interaction that was close to being statistically significant ($F_{1,426} = 3.189$, $p = 0.075$, Cohen's $d = 0.073$). The main effect was related to better performance of men on CACTT [M(SD) = 2.52(1.514) versus M(SD) = 2.07(1.535); $F_{1,426} = 9.064$, $p = 0.003$, Cohen's $d = 0.292$] and the interaction to the fact that the difference on SEFT was not significant [M(SD) = 2.25(0.948) versus M(SD) = 2.10(1.059); $F_{1,426} = 2.174$, $p > 0.14$, Cohen's $d = 0.143$].

For a more detailed picture, CFA with gender and visual performance on the two tasks (using the above-described coding) was also conducted. The results (table 2) indicated a clear pattern for men, with homogenous performance being typical and heterogeneous performance being atypical, with other configurations being in the expected range. For women the picture is less clear, with a tendency for atypicality regarding a 'CACTT-intermediate, SEFT-low' configuration and a corresponding tendency for typicality regarding a 'CACTT-low, SEFT-intermediate' configuration. A tendency for CACTT-high, SEFT-intermediate' atypicality also emerged. That is, compared with men, women seemed to have more problems with CACTT than with SEFT.

To better understand the relations among WMST, gender, and performance on visual tasks, we performed two multiple regression analyses with the number of scientific-concept-type answers and the number of questions with no answer together with gender (coded as 0 = male and 1 = female) as independent variables and SEFT and CACTT results as dependent variables. Both full models were statistically significant ($MR^2 = 0.184$, $F = 31.92$; $p < 0.001$ for CACTT and $MR^2 = 0.171$, $F = 29.21$; $p < 0.001$ for SEFT), as were all the predictors in both models: βs for the WMST score, n of missing answers, and gender were 0.23, –0.25, and –0.17 in the first model ($p < 0.001$ in all cases) and 0.29, –0.19, –0.10 in the second model ($p < 0.001$ for the first two and $p = 0.03$ for gender), respectively. That is, when accounting for the WMST, the male advantage remained significant and was more pronounced on the CACTT, which is the more difficult task. When one of the tasks together with WMST and gender were entered as predictors of the other task, gender remained a significant predictor of CACTT but not vice versa—that is, gender played a significant role in predicting task performance on CACTT when accounting for SEFT performance but did not predict SEFT when accounting for CACTT. This again implies a specific gender-related issue with CACTT.

To complement the variable-level analyses, CFAs were again carried out to understand the relationships at the individual level. WMST performance was coded as: 1 = 0–6 scientific-concept-type answers and more than 1 missing answer; 2 = 0–6 scientific concepts

Table 2. Configural frequency analysis with visual performance and gender.

Configuration		Gender	Frequency			Bonf. *p*	Type/antitype
CACTT	SEFT		obs	exp	BinPr		
Low	low	M	32	16.51	0.0003	0.0062	type
Medium	low	M	15	17.81	0.2974	1.0000	
High	low	M	0	16.15	0.0000	0.0000	antitype
Low	medium	M	13	15.29	0.3327	1.0000	
Medium	medium	M	20	16.49	0.2194	1.0000	
High	medium	M	12	14.96	0.2667	1.0000	
Low	high	M	7	33.63	0.0000	0.0000	antitype
Medium	high	M	36	36.27	0.5255	1.0000	
High	high	M	65	32.91	0.0000	0.0000	type
Low	low	F	47	18.82	0.0000	0.0000	type
Medium	low	F	12	20.30	0.0310	0.5583	antitype?
High	low	F	2	18.42	0.0000	0.0000	antitype
Low	medium	F	26	17.43	0.0296	0.5327	type?
Medium	medium	F	22	18.79	0.2547	1.0000	
High	medium	F	7	17.05	0.0046	0.0833	antitype?
Low	high	F	15	38.34	0.0000	0.0001	antitype
Medium	high	F	46	41.35	0.2447	1.0000	
High	high	F	51	37.51	0.0162	0.2908	type?

Notes. Low = 0–1 correct, medium = 2–3 (CACTT)/2 (SEFT) correct; high = maximum score.
BinPr = binomial probability; obs = observed frequency; exp = expected frequency;
Bonf. *p* = Bonferroni-corrected *p*-value; CACTT = concrete and abstract contour tracing task;
SEFT = situational embedded figure task.

and 0–1 missing answers; 3 = 7–12 scientific concepts and >1 missing answer; 4 = 7–12 and 0–1 missing answers; and 5 = 13–18 scientific concepts and 0–1 missing answers. Visual performance was coded as described above.

The results of CACTT (table 3) revealed a pattern (although without *p* adjustment) signifying that the differences between sexes increase together with WMST score. For the first WMST group there were no differences. For the second group a low score on CACTT seemed slightly more pronounced for women. For the third WMST group medium and high visual performance appeared atypical for women, while medium performance appeared typical for men. For the fourth WMST group male atypicality for low and typicality for high performance were observed, while female performance was in the expected range. For the highest WMST group high performance was typical for both sexes; however, an atypicality for low performance was observed only for men. Taken together, it appears that the visual performance for women does not improve as much with higher WMST score it does for men—that is, (some) women seem less able to benefit from more advanced word meaning structure.

For SEFT (table 4) the pattern of results was more similar across sexes, and no such clear tendencies as observed for CACTT were present.

Table 3. Configural frequency analysis with gender, CACTT, and WMST.

Configuration		Gender	Frequency			Bonf. *p*	Type/antitype
CACTT	WMST		obs	exp	BinPr		
Low	1	M	12	5.50	0.0105	0.3157	type?
Low	1	F	14	6.27	0.0049	0.1485	type?
Medium	1	M	4	5.94	0.2920	1.0000	
Medium	1	F	5	6.77	0.3297	1.0000	
High	1	M	1	5.38	0.0286	0.8580	antitype?
High	1	F	0	6.14	0.0021	0.0619	antitype?
Low	2	M	7	7.03	0.5940	1.0000	
Low	2	F	14	8.02	0.0332	0.9974	type?
Medium	2	M	10	7.58	0.2318	1.0000	
Medium	2	F	7	8.65	0.3649	1.0000	
High	2	M	5	6.88	0.3142	1.0000	
High	2	F	3	7.84	0.0457	1.0000	antitype?
Low	3	M	9	4.89	0.0601	1.0000	
Low	3	F	10	5.58	0.0566	1.0000	
Medium	3	M	10	5.28	0.0419	1.0000	type?
Medium	3	F	0	6.01	0.0023	0.0703	antitype?
High	3	M	2	4.79	0.1423	1.0000	
High	3	F	1	5.46	0.0269	0.8070	antitype?
Low	4	M	17	28.58	0.0116	0.3469	antitype?
Low	4	F	33	32.58	0.4959	1.0000	
Medium	4	M	30	30.83	0.4861	1.0000	
Medium	4	F	42	35.15	0.1326	1.0000	
High	4	M	39	27.97	0.0238	0.7126	type?
High	4	F	26	31.89	0.1606	1.0000	
Low	5	M	7	19.41	0.0010	0.0285	antitype?
Low	5	F	17	22.13	0.1555	1.0000	
Medium	5	M	17	20.94	0.2246	1.0000	
Medium	5	F	26	23.87	0.3553	1.0000	
High	5	M	30	19.00	0.0102	0.3047	type?
High	5	F	30	21.66	0.0470	1.0000	type?

Notes. CACTT: low = 0–1 correct, medium = 2–3 correct, high = max score.
WMST: 1 = 0–6 scientific concepts/> 1 missing answer; 2 = 0–6 scientific concepts/0–1 missing answer; 3 = 7–12 scientific concepts/> 1 missing answer; 4 = 7–12 concepts/0–1 missing answer; 5 = 13–18 scientific concepts; BinPr = binomial probability; obs = observed frequency; exp = expected frequency; Bonf. *p* = Bonferroni corrected *p*-value. CACTT = concrete and abstract contour tracing task; WMST = word meaning structure test.

4 Discussion

This study was concerned with the relations between verbal abilities and visual discrimination tasks (overlapping and embedded figures) from a Vygotskian perspective in a healthy adult sample with a wide age range and various educational and occupational backgrounds. Drawing on earlier reports on relationships between certain verbal tasks and performance on embedded (hidden) figures, it was hypothesised that structure of word meanings (ie propensity to think in everyday or scientific concepts as distinguished by Vygotsky 1934/1986) could

Table 4. Configural frequency analysis with gender, SEFT, and WMST.

Configuration		Gender	Frequency			Bonf. *p*	Type/antitype
SEFT	WMST		obs	exp	BinPr		
Low	1	M	11	4.24	0.0042	0.1255	type?
Low	1	F	10	4.84	0.0256	0.7685	type?
Medium	1	M	4	3.93	0.5537	1.0000	
Medium	1	F	5	4.48	0.4647	1.0000	
High	1	M	2	8.65	0.0078	0.2348	antitype?
High	1	F	4	9.86	0.0307	0.9204	antitype?
Low	2	M	9	5.42	0.0980	1.0000	
Low	2	F	12	6.18	0.0236	0.7092	type?
Medium	2	M	7	5.02	0.2402	1.0000	
Medium	2	F	5	5.73	0.4899	1.0000	
High	2	M	6	11.05	0.0740	1.0000	
High	2	F	7	12.60	0.0637	1.0000	
Low	3	M	9	3.77	0.0149	0.4474	type?
Low	3	F	6	4.30	0.2630	1.0000	
Medium	3	M	3	3.49	0.5375	1.0000	
Medium	3	F	2	3.98	0.2393	1.0000	
High	3	M	9	7.69	0.3634	1.0000	
High	3	F	3	8.76	0.0241	0.7217	antitype?
Low	4	M	12	22.05	0.0129	0.3869	antitype?
Low	4	F	23	25.14	0.3786	1.0000	
Medium	4	M	23	20.42	0.3089	1.0000	
Medium	4	F	27	23.27	0.2406	1.0000	
High	4	M	51	44.92	0.1879	1.0000	
High	4	F	51	51.20	0.5250	1.0000	
Low	5	M	6	14.98	0.0070	0.2100	antitype?
Low	5	F	10	17.07	0.0444	1.0000	antitype?
Medium	5	M	8	13.87	0.0632	1.0000	
Medium	5	F	16	15.81	0.5155	1.0000	
High	5	M	40	30.50	0.0498	1.0000	type?
High	5	F	47	34.78	0.0225	0.6756	type?

Notes. CACTT: low = 0–1 correct, medium = 2–3 correct, high = max score.
WMST: 1 = 0–6 scientific concepts/>1 missing answer; 2 = 0–6 scientific concepts/0–1 missing answer; 3 = 7–12 scientific concepts/>1 missing answer; 4 = 7–12 concepts/0–1 missing answer; 5 = 13–18 scientific concepts; BinPr = binomial probability; obs = observed frequency; exp = expected frequency; Bonf. *p* = Bonferroni corrected *p*-value. CACTT = concrete and abstract contour tracing task; WMST = word meaning structure test.

be a relevant aspect in the ability to restructure/disembed visual scenes. The effects of meaningfulness of the scene and gender were also investigated. To assess the hypotheses, two visual tasks were presented; an overlapping figures test (CACTT) and an embedded figures test depicting a meaningful scene (SEFT). Both tasks comprised concrete meaningful and abstract meaningless shapes.

First, it was hypothesised that healthy participants would not find it difficult to recognise line drawings of concrete everyday objects (whether overlapping or part of a meaningful scene).

This was confirmed and is consistent with the use of Poppelreuter's overlapping figures task as an instrument for screening cognitive impairment (eg Della Sala et al 1995; Sells and Larner 2011). The concrete figures condition of SEFT turned out to be slightly more challenging, but the difference was related mainly to one figure—the chimney—which was perhaps more difficult compared with others because it was not as easily recognisable when detached from the roof.

Our second hypothesis predicted problems in the same tasks when searching for abstract meaningless figures that violated Gestalt principles, especially on CACTT in which the intersecting of many lines overburdened the scene, thus presumably putting more demands on working memory. This was also confirmed. Many participants were unable to find any abstract figures even though they had no time constraints for solving the tasks. The difficulties were more pronounced on CACTT.

The third hypothesis proposed that the meaningfulness of the scene to be 'broken up' might pose a specific challenge, similar to that demonstrated by Bialystok (1992) for grammaticality judgments of meaningful and absurd sentences. In contrast to the general pattern, the analysis indeed identified a group of people (~11.2%) for whom the abstract figures condition of SEFT was more difficult than that of CACTT. However, contrary to our expectation, there was no relation to the structure of word meanings. The general fact that, all else being similar, meaningful stimuli are more difficult to disembed compared with meaningless ones, at least for children, has been demonstrated by Brian and Bryson (1996). Note, however, that in both of our tasks meaningful stimuli were used, but in SEFT these also formed a meaningful larger scene. This specific difficulty induced by the meaningful whole is an interesting phenomenon that warrants further investigation.

In accordance with our main hypothesis, the performance in the abstract figures condition on our overlapping and embedded figures tasks was indeed related to the structure of word meanings (ie propensity to think in scientific concepts). It is important to note that the WMST asks the participants to define and group words and describe their similarity, thus not allowing for the interpretations that were used in many previous reports on the relations between verbal abilities and performance on disembedding tasks—namely, that there is a general attentional control (eg Bialystok 1992) or disembedding ability (eg Longoni and Pizzamiglio 1981) manifesting itself in both the visual as well as the verbal domains. The WMST did not require overcoming a given context but rather assessed the meaning structure of words and corresponding principles of grouping them—that is, whether participants tended to think in abstract logical terms or terms related by everyday-experience-based associations. This lends credence to our Vygotskian account that development of language-based representations might be what is necessary for the analytical attentional control underlying the performance on these tasks rather than there being a (undefined) general ability underlying the performance in both domains.

Our last question concerned the effects of gender. The analyses indicated a male advantage in visual performance, especially for CACTT. The magnitude of the effect size of gender differences on CACTT (Cohen's $d \sim 0.3$) is in line with previous studies using individual testing on embedded figures (group testing usually yields smaller effect sizes) (Voyer et al 1995) but is especially remarkable as we used accuracy instead of the usual time measure.

In addition to having more problems with CACTT, women also seemed to benefit less from advanced word meaning structure on that task. As the main difference between the tasks was an overburdening of the scene in CACTT that arguably puts higher demands on working memory/selective attention processes, it can be hypothesised that the difference is due to the better working memory capacity in men. Although this is obviously a tentative suggestion, it is consistent with research demonstrating that working memory capacity mediates a substantial proportion of gender differences in some spatial abilities (Kaufman 2007). It would also explain the inability of some women to benefit from the more advanced

word meaning structure, as word meaning structure should be related primarily to the ability to select, organise, and manipulate information (ie to executive/analytical functions). This is possibly of little help when the capacity limits of working memory/attention are exceeded. As for the word meaning structure itself, no gender differences were present.

In conclusion, preliminary support was found for our Vygotskian proposition that language-related development might play a significant role in some visual abilities, but further research is obviously needed. These results hopefully add to the recently renewed discussion on the interplay between language and visual cognition (eg Huettig et al 2011; Lupyan 2012).

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III

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Dominant structure of word meanings moderates ageing-related decline in visual figure discrimination

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ABSTRACT

This is a follow-up study to Tammik and Toomela [(2013). Relationships between visual figure discrimination, verbal abilities, and gender. *Perception*, *42*, 971984] which established a correlational relationship between the propensity to use scientific as opposed to everyday concepts (as distinguished by L. Vygotsky) and visual figure discrimination. The purpose of the current study was to test a further prediction derived from Vygotskys theory in the context of ageing postponed start but faster rate of cognitive decline for scientific conceptual thinkers which is characteristic of cognitive reserve [Stern, Y.(2009). Cognitive reserve. *Neuropsychologia*, *47*, 20152028]. The emergence of such a pattern with age was investigated by extending the original sample of 428 participants up to age 70 with additional 119 participants older than 70 years. The hypothesis was tested with piecewise (segmented) and local polynomial (loess) regression models and was confirmed.

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Visual search; word meaning structure; language; cognitive reserve; ageing

Introduction

The question about the relationships between language and perceptual processes has a long history but has remained controversial (e.g. Gentner & Goldin-Meadow, 2003). One influential line of theorising stretches back to the psycholinguistic theory of Vygotsky (1934/1986; Vygotsky & Luria, 1994). In short, he argued that language forms a fundamental part of all higher order cognitive processes—including those that are apparently "nonverbal"—by providing new means to guide and structure one's cognition. It thereby changes the entire structure of cognitive activity (Toomela, 1996; Vygotsky & Luria, 1994). Language-based representations, however, are not uniform but develop through several stages based on their meaning structure and so, correspondingly, does cognition (Vygotsky, 1934/1986; see also Toomela, 2003a, for an elaboration of the theory). In adults particularly two types of word meaning structures—the so-called everyday and scientific concepts (Vygotsky, 1934/1986)—should be distinguished.

The "everyday" concepts are based on everyday experience with words and their referents. They are about the concrete relationships between these—the aggregates of immediate experiences and impressions *are* what the words mean (essentially the exemplar view of categorisation). So, for example, the "everyday" concept of "love" just refers to the concrete experiences and behavioural attributes that the word is conventionally used for. The meanings of this type are concrete and factual. The "scientific" concepts, on the other hand, are entirely structured within language, in relationships between words. They are about abstract logical hierarchies of word-relations, that is, formal definitions, and so are not based on immediate experiences or impressions. The "scientific" concept of "love", for example, may be based on the higher level category of "emotion" of which "love" is a specific example with certain characteristics (whatever they are defined to be).

Note that "scientific" concepts need not have anything to do with science, they just need to organise information within the system of concepts, that is, within language itself. Also, the two types of meaning structures coexist in the mind, they are not mutually exclusive (Vygotsky, 1934/1986). In addition to Vygotsky's own work, the fact that apparently the same taxonomic categories

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may actually be structurally different and the developmentally earlier ones remain relevant in adult cognition has been empirically demonstrated by K. Nelson and colleagues (e.g. Lucariello, Kyratzis, & Nelson, 1992).

Although the distinction between concrete and abstract word meanings is common and also used in some verbal IQ measures (e.g. the similarities subtest in WISC/WAIS), a connection between these theoretical constructs is not straightforward to draw. On the one hand an adept use of "scientific" concepts can be seen as *an aspect of* verbal IQ (especially due to similarities in operationalisation). The practical importance of the distinction comes from precisely the fact that some mental operations should be very hard if not impossible to achieve without relying on certain types of linguistic representations (Toomela, 2003a). So the connection to some notion of "ability" is clear. On the other hand, the theoretical status of IQ has been controversial from the start and the psychometric nature of the construct has been (in our opinion rightly) criticised from a variety of perspectives (for some relatively recent examples see, e.g. Borsboom, Mellenbergh, & van Heerden, 2003; Dennis et al., 2009; Michell, 2012; Paivio, 2014). Because the relationship between Vygotsky's ideas and newer theories of (verbal) intelligence is not uncomplicated, his (somewhat confusingly labelled) distinctions are adhered to.

In a previous study, the propensity to use "scientific" (abstract) concepts was associated with visual discrimination performance (Tammik & Toomela, 2013). The visual tasks used in the study demanded overcoming of visual clutter/distraction in order to identify some hard-to-find figures. Drawing on Vygotsky's theory it was hypothesised that the "scientific" conceptual thinking would help to suppress the irrelevant/distracting aspects of the stimuli by supporting abstract analysis of the visual scene and thus enhancing test performance. The results of the study confirmed the expected positive association between complex visual discrimination and the propensity for "scientific" conceptual thinking.

It is well documented that visual tasks such as those used by Tammik and Toomela (2013) exhibit a clear ageing-related decline in performance (e.g. Capitani, Della Sala, Lucchelli, Soave, & Spinnler, 1988; Della Sala, Laiacona, Trivelli, & Spinnler, 1995). Ageing-related cognitive decline is thought to be mainly related to some general biological changes in the nervous system[1] which can (to an extent) be compensated for (Lövdén, Bäckman, Lindenberger, Schaefer, & Schmiedek, 2010; Park & Reuter-Lorenz, 2009; Stern, 2009) and although current theorising tends to focus on neural aspects of compensation, it is worth remembering that cognitive tasks can usually be solved through different means[2] which adds a primarily cognitive dimension to compensation—people can compensate through having access to and adequately applying those different means (Lemaire, 2010; see also the distinction between flexibility and plasticity in Lövdén et al., 2010).

"Scientific" conceptual thinking was hypothesised to be related to visual discrimination performance through strategic affordances (i.e. through enabling new ways to accomplish the tasks) and is thus exactly a kind of factor that should facilitate cognitive compensation of ageing-related neurobiological deterioration. So if the reason behind the established relationship between the propensity to use "scientific" concepts and visual discrimination performance is indeed that offered by the theory, then it seems reasonable to expect that people more inclined to use "scientific" concepts should on average exhibit better performance at the same age level. Furthermore, this interaction between the use "scientific" concepts and cognitive decline should exhibit a specific pattern characteristic of so-called cognitive reserve (see Figure 1; adapted from Stern, 2009).

If comparable harmful ageing-related neural changes accumulate over time for two persons, but one of them is able to compensate for it by making use of "scientific" conceptual thinking, while the other, relying mainly only on "everyday" conceptual thinking, is not, then we would expect to see the first person maintain a level of performance despite these neural changes up to a critical point where the damage is just too great to compensate for, while the second person would exhibit a decline in performance earlier. For the first person, the decline would be

[1]The vagueness of the wording is intentional since the exact nature of the biological changes due to ageing is still a matter of active research (e.g. Rizzo, Richman, & Puthanveettil, 2014). At the same time, the specific mechanisms are not important in relation to the purpose of the present study.
[2]On tasks like those used by Tammik and Toomela (2013), solving strategies have been investigated by Pennings (1988, 1991).

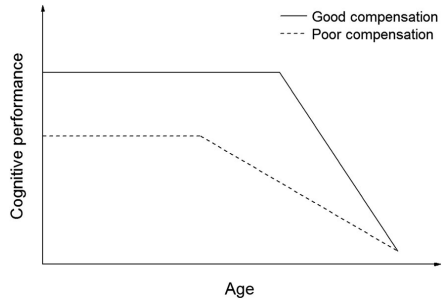

Figure 1. Expected interaction pattern (adapted from Stern, 2009).

sharper (especially when the initial performance was higher) because it only manifests when the neurobiological damage is already quite severe while for the second person the decline would be gentler, in line with the steady accumulation of neural changes. Eventually, both individuals would end up at the same floor level of performance. The same should naturally hold on the group level.

Figure 1 is of course an idealised presentation but on the general level this pattern is a reasonable expectation if the Vygotskian explanation to the relationship between the propensity to use "scientific" concepts and visual discrimination is indeed correct. The aim of the current study was to test this expectation in order to undermine or provide further corroboration to the proposed interpretation of the relationship established by Tammik and Toomela (2013). Furthermore, when confirmed, the results would also corroborate the notion of cognitive reserve (Stern, 2009) from which the expectation was derived. Concretely, the hypothesis of the study was that, on average, in the relationship between age and visual performance the decline starts later but is faster for "scientific-conceptual" thinkers compared to more "everyday-conceptual" thinkers.

Method

The method for data collection was identical to that of Tammik and Toomela (2013).

Participants

The original sample of Tammik and Toomela (2013)—428 participants (200 males) with an age range 17–69 ($M = 37.3$, $SD = 15.1$)—was extended with 119 participants (20 males) over 70 years of age ($M = 83.0$, $SD = 4.1$). The final sample consisted of 547 healthy Estonian adults (219 males) with an age range of 17–97 years ($M = 47.2$, $SD = 23.2$). The participants were chosen so as to involve people with diverse backgrounds and educational levels (years of formal education varied from 2 to 21 years) to ensure the generalisability of the results and the variability in the propensity to use "scientific" concepts. Among the +70 group there were considerably more women than men (99 vs. 20) which is loosely in line with the Estonian general population indicators (Statistics Estonia, 2012).

Materials and procedure

To assess visual discrimination abilities two different contour picture tasks were used—concrete and abstract contour tracing task (CACTT) (Toomela, 2007a) and situational embedded figure task (SEFT) (Toomela, 2007b).

The CACTT was a modified version of the Poppelreuter's task (adapted from Luria, 1980). The task comprised two test cards with line drawings of five overlapping figures of everyday objects. The overlapping figures covered 10×10 cm. For both test cards four line drawings on separate cards were presented one by one. On two cards, the exact copy of the line drawing of one of the five objects was drawn. On other two cards, abstract contours from the same overlapping figures test card were drawn so that the figure contained segments of several of the objects on the test card (see Figure 2 for an example).

Although the two types of figures—concrete and abstract—are similar from a physics perspective, our visual system automatically recognises the "everyday" objects and structures the visual field accordingly; the objects "pop out". Locating the abstract figures requires overcoming these automatic processes to view the lines as belonging to the abstract figures rather than the "everyday objects".

It was explained that the extracted figures on the separate cards are of exactly the same size and orientation as on the test card. The participants were asked to trace the contour of the single figure on the test card with his/her finger. The first single item presented was always a concrete object. There was no time constraint on finding the solution to the task. A response was coded as correct, if the person traced at least 90% of the figure drawn on the separate card. In case of

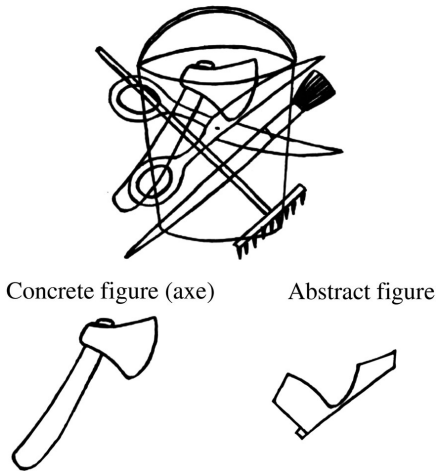

Figure 2. Example of CACTT.

doubt, the person was encouraged to trace the contour as exactly as possible. The maximum number of correct answers for concrete objects and for abstract contours was four in both cases.

The SEFT comprised a 29 × 19 cm line drawing depicting a simple meaningful scene—a house with a garden. As in the CACTT, the participants were presented with two types of figures—concrete and abstract—but this time there was no overlapping of figures, arguably making less demands on working memory/selective attention processes (see Figure 3 for examples). At the same time, the figures formed a meaningful scene thought to create a specific challenge in breaking it up (see Tammik & Toomela, 2013). Instruction and coding of answers was similar to that used in the CACTT. The maximum number of correct answers for concrete objects and for abstract contours was three in SEFT.

Both tasks were presented on paper with both the simple (to be found) figure and the large figure visible to the participant simultaneously. All verbal labels were avoided and the figures were only referred to as "it". There were no time constraints, and if the participants stated that they were not able to find the figure, they were encouraged to try again (prompts were not prespecified). Encouragement was used in order to diminish the confounding effect of low motivation. As such, it was a measure of ability to find the figure instead of efficacy of finding it. As almost all of the participants were able to find the concrete figures, only abstract figures were used in the analysis. Visual tasks were presented before the word meanings structure test (WMST) (below).

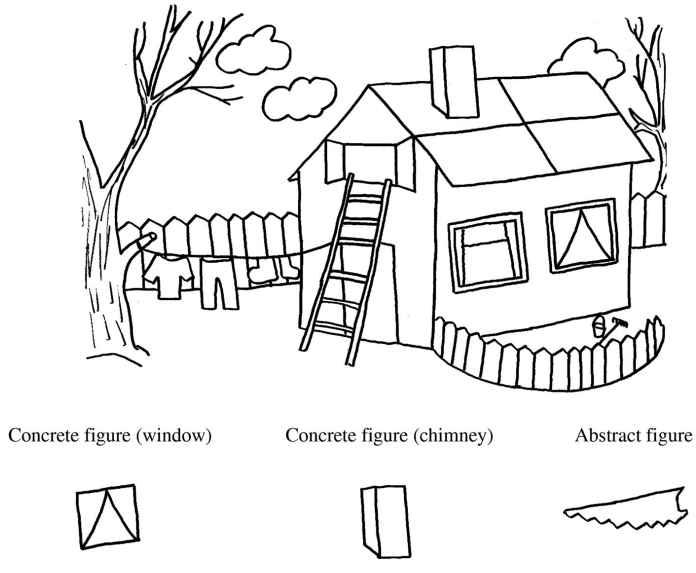

Figure 3. Example of SEFT.

The structure of word meanings or the propensity to think in either scientific or everyday type concepts (as distinguished by Vygotsky) was assessed with the WMST (Toomela, 2007c). This test consists of three complementary parts. In the first part, the participants were asked to define six concepts, half of them being concrete (e.g. school) and half abstract (e.g. republic). In the second part, the participants were asked to describe the similarity of six concept pairs, some belonging to the same category (e.g. cat-dog) while others being in a complementary relationship (e.g. horse-rider). In the last part, the participants were presented with six triplets of words (e.g. carrot-soup-potato) from which they had to choose the two that "go together" and explain why.

The free answers (not the choices) were coded as everyday concepts (coded 0) when the definition, similarity description, or reason for commonality was based on (a) sensory attributes (e.g. cat and dog are similar because both have four legs), (b) observations of everyday activities (e.g. school is where children go for learning), (c) observations of everyday situations (e.g. carrot and potato go together because they both grow in the field), (d) description of function (e.g. typewriter and pen are both for writing), (e) sharing of parts (e.g. car and bicycle go together because both have wheels), or (f) no answer (because some items are not easily answerable without scientific concepts, e.g. the similarity between horse and rider).

The answers were coded as scientific concepts (coded 1) when (a) the relationship between words were defined hierarchically (e.g. horse and rider go together because they are both living creatures) or (b) the word was related to hierarchically higher level concept (e.g. school is an educational institution). Maximum score (number of scientific concepts) in the test was 18. In addition, the number of questions with no answer was registered separately. Theoretically, the lack of any answer represents less developed form of responding compared to everyday concept type of answers. The inter-rater agreement between coders has been previously reported as very high (Cohen's κ = .91) (Toomela, 2003b).

The descriptive statistics for the variables are presented in Table 1.

Table 1. Descriptive statistics.

	Range	Mean (*SD*)
CACTT (abstract)	0–4	1.92 (1.61)
SEFT (abstract)	0–3	1.95 (1.12)
WMST	0–18	9.34 (4.02)
AGE	17–97	47.21 (23.20)

Note: CACTT, concrete and abstract contour tracing task; SEFT, situational embedded figure task; WMST, word meaning structure test; AGE, age in years.

Analysis

All of the analyses were conducted using R (R Core Team, 2014). What we were interested in was a specific interaction pattern (Figure 1). We first confirmed the existence of an interaction using a multiple regression model (Table 2). A second-degree polynomial for age was included in the model based on a preliminary check of the data using scatterplot smoothing with loess (see below). The interaction term was indeed statistically significant but only for the CACTT.

To test whether the interaction pattern was of expected shape we fit a piecewise (segmented) regression with one change-point for different groups based on the WMST score. Piecewise/segmented regression is nothing more than a combination of multiple linear regression models that are connected at certain value(s) of predictor(s). In other words, different regression models are used at different ranges of predictor values. The method is used when the relationship between outcome and predictor(s) is non-linear but can be well characterised through successive linear models (there are a few values where the relationship changes abruptly). Our theoretical expectation (Figure 1) has exactly these kinds of relationship (two straight lines connected at certain age value).

Table 2. Regression models with interactions ($N = 547$).

	Model for CACTT			Model for SEFT		
	Beta	CI	*p*	Beta	CI	*p*
WMST	0.47	0.29–0.64	**<.001**	0.40	0.22–0.57	**<.001**
AGE	1.06	0.57–1.55	**<.001**	0.58	0.08–1.07	**.023**
AGE^2	−1.19	−1.62 to −0.76	**<.001**	−0.79	−1.22 to −0.36	**<.001**
WMST*AGE	−0.00	−0.01 to −0.00	**.025**	−0.00	−0.00 to 0.00	.366
R^2/adj. R^2	.288/.282			.276/.270		

Note: WMST, word meaning structure test; AGE, age in years; Beta, standardised regression coefficient; CI, confidence interval of beta.

The tricky part, of course, is finding the optimal change-point where the regression models should "meet". We used the method by Muggeo (2003) implemented in the R package "segmented" (Muggeo, 2008) that allows to estimate all the model parameters—the change-point(s) as well as the parameters of the regression models—simultaneously, also yielding standard errors for all of them. The latter is important for judging whether differences between groups are statistically reliable.

We also fit a loess (local polynomial regression) curve to confirm that the shape of the relationship is indeed one that can be reasonably approximated by the one change-point model. Loess is a non-parametric regression method often used for scatterplot smoothing to assess the relationship between variables without explicitly specifying the function. It works by fitting a low-degree polynomial regression model for each point in the dataset using its neighboring values giving more weight to the closer ones (the degree of polynomial and the neighborhood size can be specified by the analyst) and combining the models. Since the shape of the relationship is found "automatically" and not constrained by the analyst, it is a suitable method for confirming that the segmented regression models are adequate approximations for the relationships in the data. The loess curve was fit with the standard loess() function in R using second-degree polynomial (the default) and multiple span (neighborhood size) values.

The resulting segmented and loess models were plotted and compared with the expectation (Figure 1), the criteria being the relative locations of the change-points and magnitudes of the following regression slopes between the groups.

Since the analysis required grouping based on the continuous WMST score but there were no theoretically justified criteria for choosing the cut-off values, we decided to implement the analysis as an interactive graph with changeable cut-offs. This was done using "Shiny" (RStudio & Inc., 2015). The interactive graph includes both the segmented regression and loess plots and can be accessed at https://valdart.shinyapps.io/WMS_aging_shiny/. As the older group included very few men (20 out of 119), the relationships with gender could not be reliably analysed. For those interested, the loess part of the interactive graph allows for plotting the genders separately.

Results

Table 2 presents the regression models with interaction for both tests. The interaction term was significant only for CACTT. The results of the main analysis to assess whether the shape of the interaction is in line with the hypothesis can be accessed as an interactive graph at https://valdart.shinyapps.io/WMS_aging_shiny/. The expected pattern does indeed manifest very clearly starting from cut-off score of 12. An example with cut-off at 13 is presented in the Figures 4 and 5.

Since the WMST scores were more or less normally distributed, the sample size for highest WMST group becomes smaller the higher the cut-off. The score of 12 is quite high and unfortunately group size for the highest WMST group becomes relatively small for the wide age range. This results in wide confidence intervals and in general makes the applicability of asymptotic approximations questionable. The confidence intervals for the slope estimates were thus not used.

The location and confidence intervals for the change-points are still shown by the points with "whiskers" just above the *x*-axes but should be interpreted cautiously keeping the group sizes in mind. In addition to the sample size the sometimes wide confidence intervals for the highest group based on WMST score might be related to the fact that the best change-point often falls close to age 70 where there is a gap in the data. The same gap might also be the reason for the weirdly far off change-point on the SEFT (falling just after the gap). In this case the "true best" change-point might actually be in the gap.

The results are nevertheless quite clear in relation to the hypothesis (although the cut-off on the WMST needs to be rather high). One can see from the example on Figures 4 and 5 (with cut-off 13) that on both tests the change-point is later and the rate of decline steeper for the higher group based on the WMST score compared to the lower group exactly as expected. Although the interaction term in regression model was statistically significant only for CACTT (Table 2) the patterns are in line with the hypothesis on both tests starting from cut-off values of 11 (SEFT)/12 (CACTT). The loess lines confirm that the one change-point piecewise regressions are reasonable approximations of the relationships. In sum, the results are clearly supportive to the hypothesis.

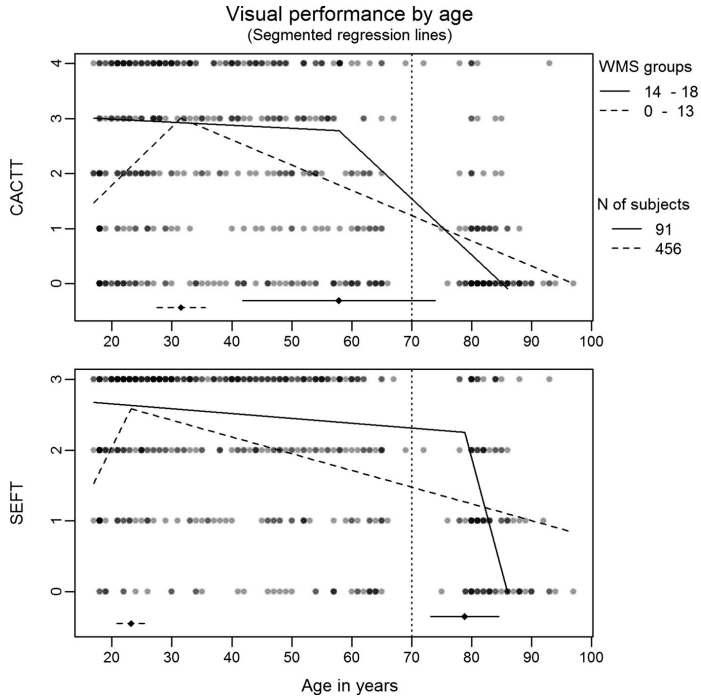

Figure 4. Segmented regression lines.

Discussion

The aim of this study was to put the interpretation of a previously established correlational relationship between the propensity to use "scientific" concepts (as distinguished by Vygotsky) and visual discrimination performance (Tammik & Toomela, 2013) to the test by making use of ageing-related decline in the latter. The reasoning was that since "scientific" conceptual thinking is supposed to be related to the visual performance through strategic affordances it is also well suited for active compensation of ageing-related biological changes and the three variables should (on the group level) thus exhibit a specific interaction pattern characteristic of cognitive reserve (Figure 1; adapted from Stern, 2009). The existence of a reliable interaction was first confirmed using a standard regression model and then an interactive graph with loess and segmented regression models was used to assess whether the interaction conformed to the hypothesised pattern.

Two different visual discrimination tasks were used. Although the interaction patterns were in line with the hypothesis on both tasks, the interaction term in regression model was statistically significant only for one test, CACTT. The fact that the results are clearer for CACTT makes sense considering that this was the harder task which makes it more sensitive to ageing-related effects as well as more suitable for compensating them. The reasoning is that in order to fail in the easier task (SEFT) the problems present probably need to be more severe which also makes them harder to compensate for compared to the more demanding CACTT with which most of the sample struggled (only about 25% of the sample received maximum score on CACTT compared to 44% on SEFT even though there were no time constraints). Presumably, already quite subtle biological changes due to ageing will affect the performance on CACTT but not on SEFT and only the subtler neurobiological damage is likely to allow for effective compensation. For example, one can ease the visuospatial working

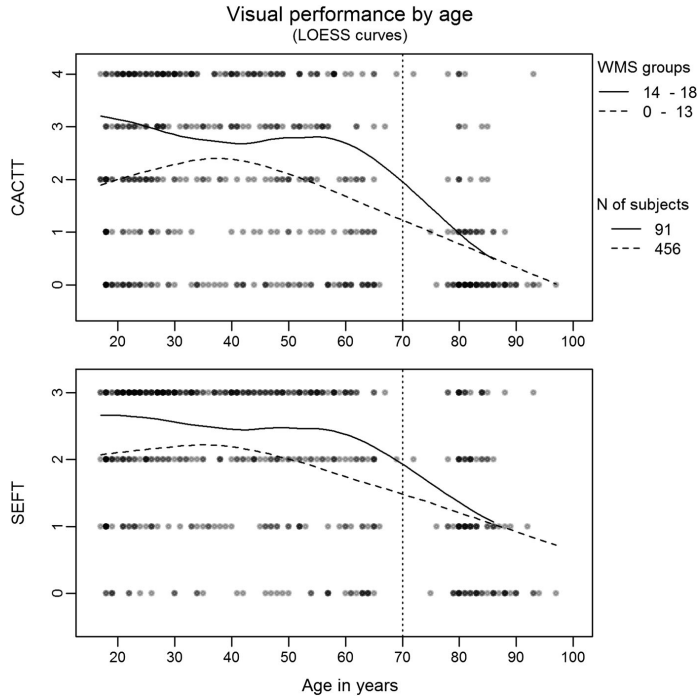

Figure 5. Loess lines.

memory load of the task[3] by analytically limiting the possible area of search but this can only help to a certain point; if the perceptual system cannot handle the demands of the task even at that point then this strategy will not boost the manifest result. So the fact that the results are more robust for CACTT compared to SEFT is actually somewhat expectable. It is also consistent with previous reports that cognitive reserve indicators are more strongly related to performance on complex cognitive tasks compared to simpler ones (Dufouil, Alpérovitch, & Tzourio, 2003; Sumowski, Chiaravalloti, & DeLuca, 2009).

Taken together the results seem clearly supportive to the theory with the group differences (from cut-offs above 12) in both the inflection points (start of the decline) as well as steepness of the curves (rate of decline) corresponding exactly to the hypothesised pattern.

Since the expectation was based on the ideas of Stern (2009), the results also corroborate his notion of cognitive reserve (which has been defined as "differences in cognitive processes as a function of lifetime intellectual activities and other environmental factors that explain differential susceptibility to functional impairment in the presence of pathology or other neurological insult" (Barulli & Stern, 2013, p. 502)). By directly confirming the hypothesised pattern they add to the results of Hall et al. (2007) who confirmed it in a clinical setting.

From a theoretical perspective, our results draw attention to a cognitive construct possibly important in explaining cognitive reserve. The often-used proxies for cognitive reserve—education and verbal IQ—are related to the word meaning structure and Vygotsky's theory could offer new insights about the underlying mechanisms of reserve from a more cognitive perspective. The "differences in

[3]The fact that these types of tasks strain visuospatial working memory has been experimentally demonstrated by Miyake, Witzkia, and Emerson (2001).

cognitive processes as a function of lifetime intellectual activities" might be partly explained by affordances of different types of semiotic representations mastered.

As noted in the introduction, the criteria used in some verbal IQ measures is similar to the criteria for distinguishing "everyday" and "scientific" concepts (i.e. the operationalisation of word meaning structure) and word meaning structure can thus perhaps be seen as *an aspect of* verbal intelligence. With the controversy surrounding the construct of IQ, the exact theoretical relationships should be clearly specified, however, because otherwise drawing these connections most likely only adds confusion. At the same time, the theory of Vygotsky is actually well suited to elucidate the nature of intelligence as it relates to language. Either way, there is an obvious methodological relationship between current results and others using similar tasks.

Despite our encouraging results some problems with the study also warrant mentioning. First, although using a large and representative sample, the study was a cross-sectional one and thus open to all the well-known problems like cohort-effects (e.g. Baltes, 1968). At the same time, longitudinal studies are also open to specific problems of their own and should not be uncritically favoured over cross-sectional ones just because they are longitudinal (Salthouse, 2010a, 2010b). In short, it is a clear shortcoming of the study that it used a simple cross-sectional design but it is not clear what the exact implications of this shortcoming are for the results.

Second, the interpretation of the results like those presented warrant caution in any case because of confounds. This is a hallmark problem of observational studies and very clear here because the relevant environmental, cognitive (representational/strategic), and biological factors are *intrinsically* intertwined—it is the environmental demand that drives the need for cognitive adjustments which in turn may result in plastic changes in the brain (Lövdén et al., 2010). People more inclined to rely on "scientific" conceptual thinking are basically bound to be different from those relying mainly on "everyday" conceptual thinking also in other respects. This is a problem especially because biological ageing, too, might be confounded, that is, WMST groups might have differed in the accumulated neurobiological damage for the same chronological age level because of different life histories. Since no objective biological measures were taken, it remains unclear how much of a problem this could have been. However, the fact that the post-change-point slopes also varied as expected (faster decline for the higher WMST group) adds some reassurance. If the main difference between groups were in biological ageing it would be more reasonable to expect that the post-change-point slopes would be the same.

Despite these issues, the results of the current work were well in accordance with the hypothesised specific pattern and are thus seen to offer support to both the Vygotskian hypothesis as well as the notion of cognitive reserve (Stern, 2009). They extend the previous results by Tammik and Toomela (2013) and draw attention to a particular psychological construct (word meaning structure) possibly important in the context of active compensation of ageing-related biological changes which is of both theoretical as well as practical importance.

Disclosure statement

No potential conflict of interest was reported by the authors.

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KOKKUVÕTE

SEOS JUHTIVA MÕISTETE STRUKTUURI JA VISUAALSE OBJEKTITUVASTUSE VAHEL

Selle uurimuse fookuses on seos keelelise mõtlemise ja visuaalse objektituvastuse vahel. Kuigi visuaalset ja verbaalset mõtlemist tänapäeva psühholoogias sageli vastandatakse, on mõjuvaid põhjuseid arvata, et need kaks nähtust on omavahel lähedalt seotud. Keele ja mõtlemise vahekorra uurimisel on vastuoluline ajalugu, kus isegi suhteliselt hiljutised seisukohad kõiguvad seinast seina: väidetest, et keel on kasulik samavõrra nagu nägemine on kasulik, omamata mingit põhimõtteliselt erilist rolli mõtlemises kuni seisukohtadeni, et keeleliselt vahendatud mõtlemine on niivõrd erinev mõtlemisest ilma keeleta, et neid ei peaks sama nähtusena käsitlema.

Suures plaanis võib erialakirjanduses eristada viit seisukohta:

1. Keel on suhtlemisvahend, mis ei puutu oluliselt *selle aluseks* olevasse mõtlemisse (nt Bloom & Keil (2001) ja Gleitman & Papafragou (2005; 2013)).

2. Keel mõjutab mõtlemist (vähemalt niivõrd) kuivõrd keelelise eneseväljenduse jaoks tuleb austada keeles levinud eristusi; pidevalt teatud eristustele tähelepanu pööramine omab mõju ka suhtlusvälises kontekstis (nt D. Slobin (1996) aga ka L. Boroditsky (2001) ja S. Levinson (2003)).

3. Keel on „tööriist“, mis võimaldab muuhulgas inimesele ainuomaseid kognitiivseid operatsioone (nt A. Clark (1998), D. Gentner (2003; 2016) ja E. Spelke (2003)).

4. Keelepõhised representatsioonid moduleerivad pidevalt asetleidvaid kognitiivseid protsesse ja mängivad seega psüühikas keskset rolli (nt G. Lupyan (2012; 2016)).

5. Keele omandamisega leiab aset psüühilise süsteemi transformatsioon, mis eristab seda põhimõtteliselt keele-eelsest psüühikast (nt Toomela, 2003; 2015; Vygotsky, 1934/1986; Vygotsky & Luria, 1994)).

Kuigi eelnev seisukohtade loetelu võib näida kontiinumina usust, mil määral keel mõtlemist mõjutab, ei ole see siiski nii ja eri seisukohtade esindajad tegelevad sageli üsna eraldiseisvate küsimustega. Näiteks on küsimus sellest, mil määral mingi spetsiifilise keele omandamine mõjutab valdajate mittekeelelist mõtlemist üsna erinev sellest, mis mõju on *keele kui sellise* omandamisel. Samuti võib olla küsimus sellest, millised kognitiivsed operatsioonid saavad võimalikuks tänu keele kasutusele, üsna erinev küsimusest, kuidas moduleerib keel automaatselt asetleidvaid mittekeelelisi protsesse.

Sellises seisukohtade mitmekesisuses on oluline alustada uurimuse aluseks olevatest eeldustest ja vastavalt järgneb lühiülevaade minu teoreetilisest lähtekohast, mis põhineb A. Toomela edasiarendusel L. Võgotski psühholingvistilisest teooriast (Toomela, 2016; 2017). Eelpool toodud loetelus paigutub see viimasesse – 5. – kategooriasse.

Keel on selle vaate järgi *sümbolite süsteem*, kusjuures sümboliks võib olla ükskõik milline kogemus (ehk representatsioon), mis omandab *konventsionaalse* suhte oma referenti. Suhte konventsionaalsus on keskse tähtsusega, sest see tähendab, et sümbolitega tuleb opereerida teiste reeglite alusel kui need, mis kehtivad referentidele. Sümbolitele kehtivad sotsiaalse, mitte füüsikalise maailma reeglid, mis avab võimaluse kvalitatiivselt uudsel viisil kogemuse sisemiseks organiseerimiseks (ehk mõtlemiseks). Lisaks võimaldab keel suunata teiste tähelepanu ja käitumist ning see võimalus rakendub samavõrra ka iseendale – keelest saab vahend ka oma käitumise reguleerimiseks.

Keelelised representatsioonid (s.t sümbolid) teevad aga läbi pika arengu, milles võib eristada (vähemalt) viit staadiumi, millest antud töö seisukohalt on oluline eristus tava- ja teadusmõistete vahel. Tavamõisted põhinevad igapäeva kogemusel sõnade ja nende referentidega: igapäevakogemuste „agregaat“ *ongi* tavamõistelise sõna tähendus. Vastavalt on selliste sõnade piirid hägused ja „agregatsiooni“ aluseks olev printsiip ei ole kasutajale teadvustatav. Teadusmõisted seevastu põhinevad sõnade (s.t sümbolite) omavahelistel suhetel ja sõna tähendus väljendub läbi tema seoste teiste sõnadega, võimaldades ka sõnade defineerimise. See omakorda paneb aluse loogilisele mõtlemisele, sest sõna defineerimise eelduseks on selle kesksete tunnuste *teadlik* abstraheerimine ja vastandamine teistele, mittemääravatele, tunnustele.

Kokkuvõttes vabastab keel nii mõtlemise kui tegevuse otseselt meeleliselt kogetava maailma struktuurist, võimaldades kvalitatiivselt uudsete representatsioonide loomise ja kasutamise iseenda käitumise regulatsioonis.

Vastavalt on keelel roll ka inimese visuaalses tajus. Võime eristada kolme erinevat aspekti. Esiteks tekivad visuaalsete ja keeleliste representatsioonide vahel automaatsed interaktsioonid, nt objekti nime fonoloogilised aspektid mõjutavad selle visuaalset tuvastamist (Chabal & Marian, 2015) ja vastupidi, visuaalne analüüs mõjutab hilisemat nimetamist (Zwitserlood, et al., 2018). Teiseks võimaldab keeleliste kategooriate õppimine taju treenimist: nt mammograafi lugedes (Nodine, et al., 1999). Samasse kategooriasse kuuluvad tõenäoliselt ka värvitaju erinevused eri keeli rääkivate rahvaste vahel (Roberson, Davidoff, Davies, & Shapiro, 2005). Kuigi seda efekti võib pidada sekundaarseks, on selge, et inimesed tajuvad maailma teisiti ja seda poleks toimunud ilma keelepõhiste kategooriate omandamiseta. Kolmandaks pakuvad keelelised kategooriad strateegilisi võimalusi oma taju juhtimisel, kasvõi ⊓⊔ ja ⊔⊓ külili 2 ja 5-na mõtestamises, et neid hulga sarnaste kujutiste hulgast kiiremini leida (Lupyan & Spivey, 2008). Loomulikult ei ole need 3 aspekti eraldiseisvad, vaid toimivad koos: nt teadlik strateegia (3. aspekt) võib harjutamise läbi automatiseeruda (2. ja 1. aspekt).

Vastavalt eelnevalt kirjeldatud mõiste arengule võib eeldada vastavaid erinevusi ka nende mõistete poolt toetatud taju protsessides: nt selleks, et mingit visuaalset sisendit geomeetriliste printsiipide alusel analüüsida, peavad antud printsiibid olema esmalt omandanud, mis omakorda eeldab teadusmõisteliste sümbolitega opereerimist. Ühes sellega saavutatakse ka suurem vabadus ja teadlik kontroll oma

taju üle: nt “teravale nukile” *vs* “nurgale” *vs*“ teravnurgale” keskendumine on psühholoogiliselt tõenäoliselt mõnevõrra erinevad operatsioonid.

Üks kontekst, kus selline efekt esile võiks tulla, on objektide leidmine peitepildilt (Joonised 1 ja 2), mida on pikalt kasutatud neuropsühholoogilise testina visuaalse agnoosia (ja teiste probleemide) tuvastamiseks. Kuigi sellisel testil on esmapilgul vähe pistmist keelega, võiks just keeleliselt toetatud analüüs aidata automaatsete segavate tajuprotsesside allasurumist ja pildi „dekonstruktsiooni“ lihtsamini hallatavateks alaosadeks. Just seda hüpoteetilist seost antud uurimuse empiiriline osa testima asuski.

I – teoreetiline – uurimus keskendus aga uurimispraktikale psühholoogias, mis, kuigi mitte otseselt seotud eelpool tõstatatud psühholingvistilise küsimusega, on keskse tähtsusega niivõrd vastuolulises uurimisvaldkonnas kui keele-mõtlemise vahekord. Uurimuse järeldus oli, et tänapäeval sageli esinev teadustegevuse mõtestamine kui „üldistamine statistilise analüüsi põhjal“ ei ole tegelikult põhjendatud ja seda oleks mõistlikum mõtestada kui abstraheerimistegevust, mille eesmärgiks on põhjuslikud teooriad (*vs* statistilised seaduspärad).

II – empiirilises – uurimuses esitati 428 inimesele vanuses 17 kuni 69 aastat kaks erinevat tüüpi peitepilti ja hinnati ka nende domineerivat mõistete struktuuri (s.t tava- või teadusmõistete kasutamist) selleks spetsiaalselt konstrueeritud testiga. Testide tulemuste vahel esines selge positiivne korrelatsioon: teadusmõistelisemad mõtlejad olid keskmiselt edukamad ka peitepiltide lahendamisel. Lisaks esines alagrupp inimesi, kelle jaoks oli eriti raske just see peitepilt, kus objekti leidmist segav situatsioon moodustas eraldiseisva terviku.

III uurimuses täiendati II uurimuse valimit veel 119 inimesega vanuses üle 69 eluaasta (vanim osaleja 97), et uurida, kas mõistete struktuur seostub vananemisest tingitud visuaalse taju languse kompenseerimisega nagu teooriast tulenevalt oodata võiks. Selleks kontrolliti spetsiifilise, kompensatsiooniga seotud, langusmustri (Joonis 3) esinemist, mis leidis ka kinnitust (Joonis 4).

Kokkvõttes on tulemused kooskõlas teooriast tuletatud eeldustega, pakkudes seega teooriale empiirilist tuge. Lisaks võimaldavad tulemused varasemate sarnaseid meetodeid kasutanud uurimuste alternatiivset tõlgendamist. Edasised uurimused võiksid keskenduda leitud seose aluseks olevate strateegiate ja mehhanismide täpsemale tuvastamisele ning samuti tulemuste kordamisele teistes modaalsustes (nt taktiilne objektituvastus), sest teoreetilisest perspektiivist pole modaalsusel otseselt tähtsust.

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