

Antônio José de Bastos Leite, Francisco Carlos Paletta, Maria Fernanda da Silva Martins, Teresa Silveira

The Role of Neuroscience in information and knowledge appropriation

Abstract

Understanding how knowledge should be organized, requires for information & library science to embrace brain science as a full partner. This brings with it a new perspective from information behavior; on the basis that behavior should constitute reading skills, memory and thinking. Currently, the reading behavior of “Digital Natives” versus “Digital Immigrants” has been the object of attention in several areas of knowledge, such as sociology, psycho sociology, and information science. Brain science, together with imaging, have also approached the problem of reading, connecting it with memory and thinking. This research deals both with reading and information science, as well as neuroscience, neuroimaging and cognitive psychology. The aim of this research is to differentiate the areas of the brain that are activated in individuals belonging to the generations born in the digital context and in those who have adapted to it. In terms of methodology, the study participants consisted of 24 right-handed male individuals, 12 of whom, aged between 19-30 years old, comprised the subgroup of “digital natives”, while the other 12, aged 42-50 years old, served as “digital immigrants”. A condition involving sequential reading (TpA), and a condition involving digital reading (TpB) were used. At the end of the fMRI scanning, participants were asked a set of questions, to assess their degree of understanding, retention and capacity to use information from the fMRI paradigm. The results did not reveal major differences in global terms. However, significant differences were detected between the two conditions of the paradigm, by contrast TpB - TpA, in the right fusiform gyrus in both groups. The peak of statistical significance occurred at coordinates 33 -52 -14. The questionnaire revealed differences between groups. We conclude that differences found in the results of the questionnaire could be related to the effect of distractibility on the retention of information when other stimuli are shown concomitantly to the sequential reading. Certainly, future cognitive tests and imaging work focused on the processes underlying the attention, memory and use of information should be done to clarify this. In the meantime, information professionals need to consider information according to the binomial “push and pull”; that is, products and services should deliver answers to the users but at the same time should encourage them to get more, to explore different perspectives. Increasing curiosity is the key to personal knowledge development. Finally, information products and services should avoid the current information trend, in some way expressed in this research, of get in, get the answer and get out. This leads us to the main challenge, namely that organizing knowledge reinforces the focus on user knowledge and the need for brain science and physiology to secure thinker users instead of information reactive ones.

Introduction

In information science, the study of informational behavior involves the consideration of the effect that lived experience has over the individual (one's mind), as well as the impact that the environment has in the functional development of one's brain. This latter concern seems to be more implicit, perhaps because it demands the establishment of scientific connections between two fields which traditionally have had difficulty in dialoguing: exact or life sciences and social sciences. Hence, one of the challenges of this research: sustainable interdisciplinarity.

Accordingly, to describe a technological experiment conducted in this scientific domain, our attention must first be drawn to two key concepts: digital inclusion and digital literacy. Whereas the former is widely associated with operational issues in the domain of equipment, the latter invites complexity into our reflections, since it adds to the operational domain both an informational domain and a reader. In other words, to evaluate the attitudes of the reader, how he uses information and develops knowledge, involves understanding how he retains this information. In order to do this, it is necessary to investigate how a subject reads and how he processes and retains what he has read. In practical terms, this means determining the level of reading competence and the brain areas which are activated during reading, relating this information to the attitude the reader showed in the ways he uses and develops personal knowledge. Thus, this study aims to verify to what extent the new formats of reading influence the retaining and use of information in individuals who clearly grew up in the context of technological mediation. In practical terms, we intend to:

- Differentiate the brain areas which are activated during the reading of static formats (text) and dynamic formats (animated text and image), both for subjects who were born in an age of early contact with digital formats and those who had to adapt to them at a later age.
- Relate this information to the informational behavior of these subjects (how they retain and use information) using the results obtained, relating to the future of information users, of information services and products, as well as of informational professionals.

An interdisciplinary approach to informational behavior

Whereas biological sciences describe in a single manner the way the brain activates different capacities and transforms them into competences, social and human sciences offer multiple designations for the generation born after the 70s/80s. In the literature, the description of the processes that activate the brain to become a reader refers consistently to the same concepts: use during the sensitive periods (especially those which occur between birth and 3 years of age, and between 6 and 12 years of age), the workings of memory, both repetitive and elaborative (Wolfe 2004), the need to develop/exercise memory and the control of selective attention. The same consistency is not found in the literature when describing cognitive functions. The term “digital native” is one among many such designations, others including “new millennium learners” (Pedró 2006), “net generation” (Tapscott 1999), “gamer generation” (Carstens and Beck 2005), “generation Y”, “generation M” (media), “generation V” (virtual), or even “generation C” (Veen and Vrakking 2006; Rideout *et al.* 2005), in which “C”, according to the authors, refers to three behaviors/functions characteristic of this generation: connectivity, creativity and click. This plurality of terms for those who were born in a digital environment is not found in the literature in reference to the

previous generation. The most common designation is “digital immigrants”. However, taking into consideration the abundance of labels for the former group, we could ask ourselves if this amounts to different representations of this generation.

Methodology

Participants

Our sample was composed of 24 right-handed male subjects, without any neurological alterations, who did not take any medication capable of influencing cognition. These 24 subjects made up two subgroups: 12 “digital natives” between the ages of 19 and 30, and 12 “digital immigrants” between the ages of 42 and 50.

The choice of a sample composed entirely of male subjects was made as a result of previous studies (Silveira 2011) which showed that male participants had a significantly more homogeneous reading behavior than female participants.

The age groups selected correspond to generations which were born and raised in distinct technological contexts (*i.e.*, before and after the digital environment). No participants were chosen above the age of 50 in order to prevent possible biases resulting from the aging process. Likewise, no participants were chosen below the age of 18 so as to guarantee full reading capacity and competence.

To be selected as volunteers and take part in the study, the candidates had to fulfill the following conditions: (a) master the required reading competence, that is, decode, understand, and interpret written messages; (b) have a minimum reading speed; (c) have or be in the process of obtaining an undergraduate degree at university; (d) differentiation regarding the implicit educational contexts.

To ensure the fulfillment of these prerequisites, especially (a) and (b), a number of activities were carried out prior to the realization of functional magnetic resonance imaging (fMRI) studies and the application of post-fMRI questionnaires.

All the candidates were subjected to: (1) a questionnaire for the characterization of the sample, so that we could get to know and understand reading habits, learning contexts, and the development of reading taste; (2) an assessment of reading competence, with the purpose of ensuring that none of the volunteers were purely functional readers; in other words, candidates should have been able to interpret the texts perfectly; (3) an assessment of reading speed, with the purpose of warranting behavioral homogeneity with regard to reading speed, as well as the adequacy of this reading speed according to the paradigm of functional magnetic resonance imaging. Candidates should have been able in 40 seconds to read a block of text with characteristics similar to those of the text used in the study.

Instruments

The research instruments used in the study were: a semi-closed questionnaire, previously to the fMRI; a functional magnetic resonance imaging study, undertaken during the progression of the block structure detailed below; and a closed questionnaire, after the fMRI (Quivy 1998).

A – Functional magnetic resonance imaging protocol

Images were obtained using a magnetic resonance equipment model 3 Tesla (Magnetom Trio, A Tim System, Siemens, Erlangen, Germany) equipped with a 12-channel antenna.

An fMRI sequence was obtained based on the BOLD signal with the following characteristics: echo time [TE] = 35 ms, repetition time [TR] = 3000 ms, *flip angle* = 90°, *field of view* [FOV] = 192 mm, section thickness = 2.5 mm, no interval between sections, number of repetitions = 200, acquisition matrix = 92x92, spatial resolution = 2.5x2.5x3 mm, acquisition time = 10 minutes.

A T1-weighted, high resolution sequence was also obtained with the following characteristics: TE = 3 ms, TR = 2300 ms, *flip angle* = 9°, inversion time = 900 ms, FOV = 240 mm, section thickness = 1.2 mm, number of sections = 160, acquisition matrix = 256x256, spatial resolution = 1x1x1.2 mm, acquisition time = 9:14 minutes.

B – fMRI data collection

A block structure was used alternating eight periods of rest with seven blocks of activity, consisting on the reading of an excerpt from Lewis Carroll's *Alice's Adventures in Wonderland* (cf. Figure 1 in the annex).

The length of each block was 40 seconds. The periods of activity were subdivided in two conditions: sequential reading, without the interference of animations or additions over the written text (TpA); and reading of the same text with the interference of animations (i.e., illustrative images and movements). Figure 4 represents the block structure. At the end of the fMRI session, the participants were asked to answer a set of questions.

C – Image processing and analysis

We used the *Statistical Parametric Mapping* (SPM) software for spatial processing, which included the realignment of functional images, the segmentation of the weighed structural images into T1, the co-registration between structural and functional images, as well as the normalization of functional and structural images for a template standard with a 1x1x1 mm spatial resolution. We also applied a smoothing algorithm to functional images, with full-width at half maximum Gaussian kernel of 6x6x6 mm.

fMRI results were obtained through a standard SPM analysis of global brain activity. This type of analysis used the general linear model based on the codified

stimuli in the visualization conditions. Movement parameters based on the realignment procedure and high-pass filters at 128 seconds were also used.

D – Post-fMRI session questionnaire

This questionnaire, the objective of which was to assess the degree of comprehension of the fMRI paradigm and test the levels of retention and use of information, was composed of three closed-answer questions. These questions, with differing levels of difficulty, aimed at evaluating the ability to understand direct textual messages, and to retain the details and the subtlety of the written message. This instrument was also intended to verify the impact that animations in the reading may have on the processing/retention of textual information.

Each of the three questions offered five options of answer, among which the volunteers had to select only one. Additionally, the participants were asked to make a drawing about the message they had read, which was expected to represent faithfully that message. Inconsistencies in terms of omission or addition in relation to the content shown were registered and evaluated under a nominal variable

Results

Functional magnetic resonance imaging

These results showed no significant differences in global terms. Specifically, no statistically significant differences were detected between the groups of “digital natives” and “digital immigrants”, as shown in Figure 2 in the annex.

However, significant differences were detected between the two conditions in the paradigm, in the contrast between TpB and TpA, in the right fusiform circumvolution, as shown in Figure 3. The peak of statistical significance occurred at the coordinates 33 – 52 – 14 (marked in red in the table of Figure 3), in a “voxel” of the right fusiform circumvolution, located in part of the right temporal and occipital lobes.

Questionnaire

Taking into consideration the questionnaire, a statistically significant difference was found. It occurred in question 2 (Q.2), table 1, which was designed to test the capacity of detecting and retaining text minutiae, differently from what was intended by questions 1 and 3. In these questions, no statistically significant difference was found, as it can be seen in tables 2 and 3 below.

Table 1: Retention of unread information - Q.2

	Frequency (yes)	Frequency (no)	$\chi^2_{(1)}$	p
Natives	1	11		
Immigrants	7	5	6,750	0.009

Table 2: Retention of unread information - Q.1

	Frequency (yes)	Frequency (no)	$\chi^2_{(1)}$	<i>p</i> .
Natives	8	4	0,202	0,653
Immigrants	9	3		

Table 3: Retention of unread information - Q.3

	Frequency (yes)	Frequency (no)	$\chi^2_{(1)}$	<i>p</i>
Natives	8	4	0,889	0,346
Immigrants	10	2		

As far as information use is concerned, statistically significant differences were found when the two groups were compared. Even though the issue we address below was not originally intended to be analyzed in this study, it seemed interesting to show the results we obtained when the subjects were asked to make a drawing illustrating what they had read. A statistically significant difference was found between the groups, as shown in table 4 below.

Table 4: Use of information

	Frequency (yes)	Frequency (no)	$\chi^2_{(1)}$	<i>p</i>
Natives	1	11	16,667	0,000
Immigrants	11	1		

In the execution of this task, “digital natives” almost always added to the central character – Alice – a small number of elements about/relative to the action of the character, not seen during the animated reading period. On the other hand, “digital immigrants”, when facing/executing the same task, no more than/only replicate the visual elements seen during the period, without adding to it any other details.

Discussion

The results show that there are similarities and differences between the groups in the study. The fMRI study showed that “digital natives” and “digital immigrants” do not activate different brain structures when these subjects read a text. Nevertheless, animated-format reading differs from sequential reading regarding the activation of the right fusiform circumvolution. This area has very important functions, since it is involved in facial recognition, color information processing, as well as in the recognition of words and in the identification of categories of variables (Mascaro 2008). Additionally, it is implicated in a wide network of attention processing: when we focus

on a point or an object in space, there is an increase in the blood irrigation and in the electric activity in the fusiform circumvolution (Mascaro 2008).

Attention plays a very relevant role in different brain functions, since there is the engagement of brain structures and processing networks related to sight, to hearing, to touch, and to the memory, which, collectively, allow for the construction of what we learn to recognize (Mascaro 2008). Thus, the fact that the activation of the right fusiform circumvolution does not occur in the same circumstances in the two reading conditions of our study, in either of the groups, might mean that the introduction of other elements, in addition to the written text, could be perceived as an “add” and not as part of the text *per se*.

A study published in 2009 by Gary Small *et al.* suggested that internet search – which requires the combination of text and images – when focused on a specific objective, even if subjected to different types of stimulation, improves cognitive performance. In this study, individuals with excellent capacity and competence in reading and navigating the internet activated more brain areas than those who did not possess these capacities/competences (*vide* Activations for the book Text reading and internet searching task in comparison with the baseline nontext bar task).

In the same direction, the present results seem to indicate that the multi-stimulation of the written text may improve cognitive functions and the working of brain structures, as long as reading capacity and competence are automated processes. However, permanent exposure to technologies and their use, especially in a situation of precocious overstimulation, when the brain is in very malleable stages, could be harmful.

This possibility encourages us to engage in a future investigation about this issue, namely, examining the consequences of overstimulation in the filtering, processing and use of information in individuals who modeled their brain structure and function to respond to multiple simultaneous stimuli.

Although this is not intuitive, the absence of demonstrable differences in the “reading brain” between the two groups does not invalidate Interlandi's words: the brain's flexibility (plasticity) to adapt and change its output is based on new and reinforced informational stimuli or inputs (2008). In other words, even though “digital natives” are subjected to new stimuli and inputs more often (and earlier in their lives) than “digital immigrants”, the recruitment of brain systems involved in reading can be identical and, it should allow (in optimal conditions) both “natives” and “immigrants” a truthful and flexible interpretation of the world.

Studies that follow from what we present here should also have a more significant sample, compensating for one of the limitations of this investigation. We would like to point out that there were no significant differences between the groups in the oppositions that we tested, except between the conditions of “digital reading” versus

“sequential reading”, be it in the “natives” or in the “immigrants” group.

Conclusions

The results of this investigation demonstrated the absence of differences between the groups, particularly at a structural level, which, from our perspective, attributes extra responsibility to future information services and professionals, since as they deal with/manage information (as a product, a service, and a system), they prepare contexts that impact the users, namely in the development of intelligence, i.e., in their capacity to receive information, deal with it and produce efficient answers (Marina 1995).

Although libraries are no longer the premier place of access to information, they will be (in fact, they already are) places that condition and predispose subjects to acquire knowledge, generating states of pleasure, realization, and fulfillment of an objective. This place is intended for a user with an increasing difficulty to memorize read information when subjected to simultaneous stimuli, and with bigger concentration difficulties, with an impact on interpretation. We believe they developed a “get in, get the answer, get out” informational behavior (Thompson 2013).

In this sense, to predict the definition of informational behavior, the manner in which it will develop knowledge, and how the future reader will use that knowledge becomes a challenge, but it foresees a change in how information professionals must be prepared, and how they must think about information products and services. With regard to their qualification, it is expected that they should be well-educated, well-informed, able to deal with both human and technological issues, able to understand the essence of their work, not just as “manipulation” of materials, but as “serving” people in an ever more complex environment in terms of “noise” as well as of capacity of choice. This “new” information professional is not just a provider of information, but also an educator.

Regarding their role in the creation of information products and services, we hope that these professionals should be able to ensure unrestricted access to geographical and temporal spaces, conceiving and testing new means of information organization and retrieval: meaning and/or search for the source of meaning. This requires that they change their attitudes to the way they conceive, develop and implement information products and services. The logic of the “pull” environment should be substituted by the principle of the “push” environment. In practical terms, this means that information products and services should focus on personalization. Push logic requires a vision, a definition and a conditioning of the informational object even before we begin the search for it.

Acknowledgment: FAPESP Research Project – Processo 2016/07358-6.

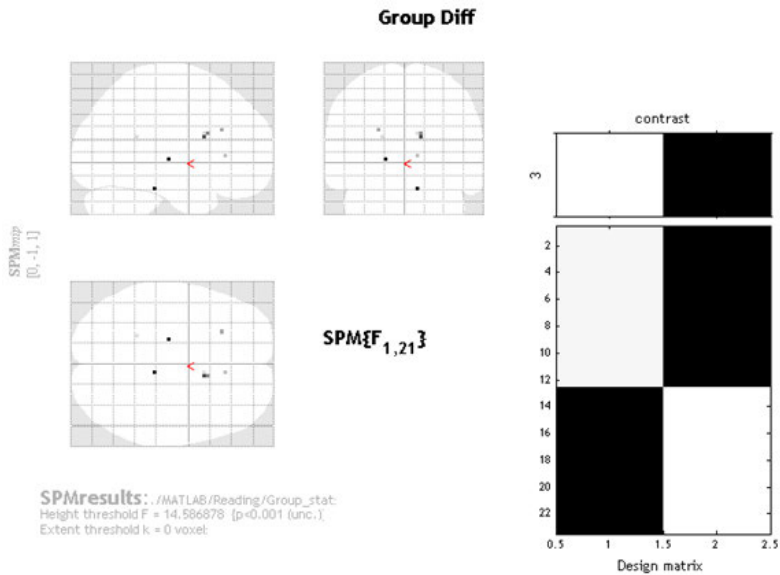
References

- Carstens, A. & Beck, J. (2005). Get ready for the gamer generation. *TechTrends: linking research & practice to improve learning*, 49(3): 22-25.
- Interlandi J. (2008). Mysteries of memory. *Newsweek.*, 152 (12) 64.
- González, AT (2005). *Los Estudios de necesidades y usos de la información: fundamentos y perspectivas actuales*. Gijón: Ediciones TREA.
- Marina, J. (1995). *Teoria da Inteligência Criadora*. Lisboa: Caminho.
- Mascaro, L. (2008). *A Arquitetura do Eu*. (4ª ed.). Rio de Janeiro: Elsevier.
- Pedró, F. (2006). *The New millennium learners: challenging our views on ICT and learning*. Paris: OECD-CERI.
- Perfetti CA, Liu Y, Fiez J, Nelson J, Bolger DJ, Tan LH. (2007). Reading in two writing systems: accommodation and assimilation of the brain's reading network. *Bilingualism-Language and Cognition*, 10(2): 131-146.
- Prensky, M. (2001). Digital Natives, Digital Immigrants. Part II: Do they really think differently? *On the Horizon*, 8(6): 3-6.
- Silva, A., Ribeiro, F., & Martins, F. (2010). Information Science and Cognitive Psychology: a theoretical approach. In International Symposium on Information Management in a Changing World, 2nd, Ankara, 2010 - *Technological convergence and social networks in information management: proceedings*. Ed. Serap Kurbanoglu, et al. Berlin; Heidelberg: Springer, p. 189-199.
- Silveira, T. (2011), *O Cérebro em mudança na era da informação: estudo sobre o comportamento leitor dos adolescentes do norte de Portugal*. Master dissertation presented to Universidade Católica do Porto.
- Small, G. W., Teena, D. Moody, Siddarth, P. & Brookheimer, S. (2009). Your brain on Google: Patterns of cerebral activation during internet searching. *Am J. Geriatric Psychiatry*, 17(2): 115-126.
- Tapscott, D. (1999). *Growing up digital: the rise of the net generation*. New York: McGraw-Hill.
- Wilson, T.D. (2000). Human information behavior. *Informing Science* 3(2): 49-56.
- Veen, W. & Vrakking, B. (2006). Homo Zappiens: growing up in a Digital Age. Continuum: London. In: Selwyn, N. (2009). *The Digital native: myth and reality*. Aslib Proceedings, 61(4): 364-379.
- Wolfe, P. (2004). *Compreender o funcionamento do cérebro e a sua importância no processo de aprendizagem*. Porto: Porto Editora.

Figure 1: Representation of the block design of Fmri



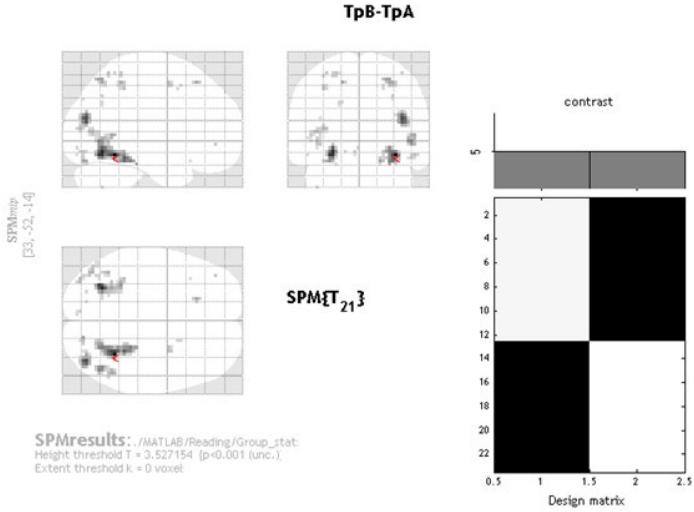
Figure 2: Results (Difference of Groups)



Statistics: p-values adjusted for search volume

set-level		cluster-level				peak-level					min mm mm	
P	C	P _{FWE-corr}	q _{FDR-corr}	k _C	P _{uncorr}	P _{FWE-corr}	q _{FDR-corr}	F	(Z _z) ²	P _{uncorr}		
1.000	6	1.000	0.530	1	0.530	1.000	0.993	15.91	3.21	0.001	9	-31 -23
		1.000	0.530	1	0.530	1.000	0.993	15.76	3.20	0.001	-38	-19 1
		0.997	0.530	3	0.247	1.000	0.993	15.46	3.17	0.001	12	11 19
		1.000	0.530	1	0.530	1.000	0.993	14.95	3.12	0.001	-24	26 25
		1.000	0.530	1	0.530	1.000	0.993	14.81	3.11	0.001	9	29 4
		1.000	0.530	1	0.530	1.000	0.993	14.62	3.09	0.001	-21	-46 19

Figure 3: Reading condition TpB– TpA (1)

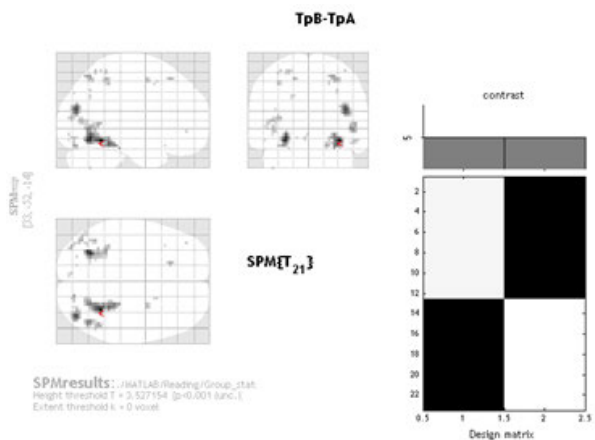


Statistics: p-values adjusted for search volume

set-level		cluster-level				peak-level					mm mm mm
p	c	p _{FWE-corr}	q _{FDR-corr}	k _c	p _{uncorr}	p _{FWE-corr}	q _{FDR-corr}	T	(Z _p)	p _{uncorr}	
0.006	31	0.000	0.000	94	0.000	0.019	0.100	6.97	4.96	0.000	33 -52 -14
						0.521	0.359	5.41	4.24	0.000	19 -43 -23
						0.823	0.543	4.31	3.97	0.000	17 -64 -11
		0.001	0.000	77	0.000	0.094	0.180	6.24	4.64	0.000	-27 -64 -11
						0.946	0.748	4.64	3.91	0.000	-70 -46 -19
						0.919	0.748	4.15	3.66	0.000	-17 -15 -11
		0.015	0.000	44	0.001	0.296	0.295	5.73	4.40	0.000	39 -79 19
		0.002	0.035	29	0.005	0.032	0.543	4.95	3.99	0.000	40 -67 -2
						0.297	0.748	4.74	3.61	0.000	51 -15 4
		0.310	0.102	18	0.020	0.983	0.748	4.45	3.69	0.000	24 -67 55
		0.988	0.459	4	0.237	0.985	0.748	4.43	3.68	0.000	-18 -26 52
		0.796	0.290	9	0.084	0.990	0.748	4.38	3.65	0.000	18 -82 -20
						1.000	0.955	3.94	3.37	0.000	11 -81 -11
		0.971	0.416	5	0.188	0.992	0.748	4.34	3.63	0.000	30 -46 52
		0.988	0.459	4	0.237	0.996	0.772	4.28	3.59	0.000	33 -79 -20
		0.796	0.290	9	0.084	0.997	0.776	4.24	3.56	0.000	-42 -58 -2
		0.244	0.092	20	0.015	0.989	0.776	4.20	3.54	0.000	-42 -73 7
						1.000	0.914	3.53	3.13	0.001	-48 -67 -2
		0.902	0.348	7	0.123	0.999	0.796	4.13	3.49	0.000	-36 -85 10
		0.902	0.348	7	0.123	0.999	0.796	4.12	3.49	0.000	30 -1 52
		0.942	0.391	6	0.151	1.000	0.844	4.06	3.45	0.000	-36 -43 46
		0.971	0.416	5	0.188	1.000	0.895	3.98	3.40	0.000	-24 -58 61
		0.735	0.290	10	0.070	1.000	0.895	3.97	3.39	0.000	51 -58 -14
		1.000	0.565	1	0.565	1.000	0.895	3.89	3.34	0.000	-39 44 -5
		0.999	0.565	2	0.404	1.000	0.895	3.89	3.33	0.000	-33 -46 61
		1.000	0.565	1	0.565	1.000	0.926	3.81	3.28	0.001	39 -52 61
		0.999	0.565	2	0.404	1.000	0.926	3.78	3.26	0.001	-6 -85 -11
		1.000	0.565	1	0.565	1.000	0.926	3.77	3.25	0.001	-42 -64 -44
		0.999	0.565	2	0.404	1.000	0.926	3.74	3.24	0.001	21 11 49
		1.000	0.565	1	0.565	1.000	0.926	3.74	3.23	0.001	30 -64 40
		0.997	0.555	3	0.305	1.000	0.934	3.66	3.19	0.001	-21 -64 34
		1.000	0.565	1	0.565	1.000	0.934	3.66	3.18	0.001	-3 -88 -8

table shows 3 local maxima more than 8.0mm apa

Figure 4: Reading condition TpB– TpA (2)



Statistics: p-values adjusted for search volume

set-level		cluster-level				peak-level				mm mm mm	
p	c	P _{FWEcorr}	√t _z corr	k _c	P _{uncorr}	P _{FWEcorr}	√t _z corr	T _p	P _{uncorr}		
1.000	0.565	1	0.565	1	0.565	3.000	0.804	3.65	3.10	0.002	-25 -79 -12
1.000	0.565	1	0.565	1	0.565	3.000	0.804	3.64	3.17	0.002	-26 -20 -20
1.000	0.565	1	0.565	1	0.565	3.000	0.804	3.63	3.15	0.002	-51 -47 -24
1.000	0.565	1	0.565	1	0.565	3.000	0.804	3.60	3.14	0.002	-39 -79 28
1.000	0.565	1	0.565	1	0.565	3.000	0.804	3.60	3.14	0.002	-24 -79 -23
1.000	0.565	1	0.565	1	0.565	3.000	0.802	3.56	3.13	0.002	30 -82 37