Thinking Outside the Cube:

Modeling Language Processing Tasks in a Multiple Resource Paradigm

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Abstract

This paper sets out to find an alternative to Wickens' cube in order to better visually represent the different resource pools recruited by complex language processing tasks. The model's two principal shortcomings, i.e. its inability to visually account for the notion of general resources and the difficulty to visually represent the tasks and their structural proximity, are addressed and compensated for by redrawing the cube and eventually abandoning the three dimensional design in favor of a two dimensional model, the so-called cognitive resource footprint, which we believe to be a more intuitive reflection of the resource involved in these tasks.

Index Terms: simultaneous interpreting, multiple resource model, cognitive load, cognitive resource footprint

1. Introduction

In the early eighties, Wickens [1, 2] presents a collection of compelling empirical evidence challenging Kahneman's [3] hitherto widely accepted single resource theory, according to which all tasks and mental activities draw on one undifferentiated pool of resources. In fact, the latter does not seem to allow for time sharing between two resource demanding tasks [4] unless they rely on discreet input and output structures. Wickens' [1,2] multiple resource theory, on the other hand, is able to accommodate such findings by presenting an account positing that the competition is not for the structures themselves but for the resources enabling these structures to function. The multiple resource model has since been used successfully in describing and modeling cognitive processing load in complex multi-modal process-control environments [5-7], hence our idea to apply this model to describe complex language processing tasks which to date have been underspecified in terms of the underlying cognitive resources they recruit.

2. Simultaneous interpreting

Simultaneous interpreting (SI), i.e. the process whereby the interpreter (I), sitting in a sound proof booth, listens to a message delivered in a source language (SL) and renders the same message in a target language (TL) in real time, is considered to be among the most complex and demanding language processing tasks [8-14], and an archetypal example of time sharing.

In an attempt to provide a simple conceptual framework for SI, Gile [8, 15] presents the "effort model" describing the complex task of simultaneous interpreting as a combination of three discrete yet related component tasks (i.e. efforts): comprehension, memory and production. The latter are assumed to recruit cognitive resources form one single pool [3] and to be managed by the coordination effort, which itself requires cognitive resources, an assumption corroborated by experimental [16] evidence. The single resource paradigm predicts that the process will break down (or parts of it delayed) when the total capacity requirement for the four tasks (listening, memory, production and coordination) exceeds the total capacity available. However, Gile concedes that some of the cognitive components probably overlap [15], suggesting that only a more detailed model taking into account which of the memory components and processes compete for the same resources and which ones do not, will allow us to identify specific problems or difficulties in SI. We believe that multiple resource theory in general, and Wickens' multiple resource model in particular, provides a better framework to describe the cognitive resource architecture at play during complex language processing tasks.

3. The multiple resource model

Wickens' three-dimensional model (with an embedded fourth dimension of focal and ambient visual processing) of multiple resources posits the existence of different "categorical and dichotomous dimensions that account for variance in time-sharing performance" [16:163]. The first dimension, i.e. processing stages, reflects the dichotomy between a shared pool of resources for perception and cognition (i.e. central processing) and a functionally separate pool of resources used for response processes [1, 17]. The second dimension, i.e. processing codes, distinguishes between manual/spatial and vocal/verbal processes, primarily based on experimental evidence suggesting that discrete manual and verbal tasks are time-shared more efficiently than two manual or two verbal tasks [18, 19]. The third dimension, i.e. processing modalities, refers to whether input and response happen aurally or visually. The model suggests that inter-modal processes interfere with one another (or each other) less than intra-modal processes [20]. The fourth and final dimension, i.e. visual processing, reflects the dichotomy between focal and ambient vision, and is embedded in the visual modality concerning both spatial and verbal codes. Both visual channels are supposed to tap into discrete resources and allow for efficient time-sharing [21]. Above and beyond the pools of dedicated resources Wickens concedes the existence of a residual pool of general resources which, albeit not reflected in his model, is available to and demanded by all tasks, modalities, codes and stages as required. Overall, the multiple resource model predicts substantial interference between resource-demanding perceptual tasks and cognitive tasks involving working memory to store or transform information [16], as is the case in language production and perception.

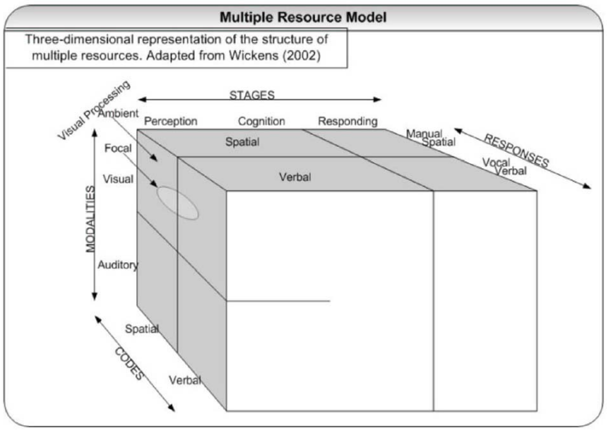

Figure 1: *Wickens' cube*

Although the visual representation of Wickens' [2, 16] model, i.e. the cube (figure 1), allows a comprehensive illustration of the above principles, it falls short of the notion of general resources which, according to the author, can be allocated to all tasks. What is more, although the conflict matrix (figure 3) allows the arithmetic calculation of an interference coefficient between two parallel tasks, the three-dimensional nature of the cube makes it difficult to graphically illustrate the structural proximity of such tasks as, at any given time, at least three sides of the cube remain hidden to the eye of the observer. It is with a view to compensating for these two shortcomings that an attempt was made to capture the notion of the multiple resource model in a different visual form.

3.1. Morphing the cube

The first challenge, i.e. finding a way to include the notion of a general capacity pool without distorting the symmetry of the three dimensional model merely requires some thinking outside the cube. In fact, the explanatory power of Wickens' cube can be preserved and even enhanced, by using a pyramid (figure 2) which can accommodate the general pool of resources at its very top. The second challenge is related to the fact that a three dimensional figure like a cube, or a pyramid for that matter, would always remain partly concealed when represented on a two dimensional medium. The obvious solution thus is to transform the three dimensional illustration into a two dimensional one, which in the case of a pyramid can be achieved by providing a top-down perspective. Whilst preserving the explanatory power of Wickens' original model (although the visual distinction among the three processing stages becomes less evident), this two dimensional model allows for an uncomplicated illustration of the structural proximity of concurrent tasks revealing what we refer to as the cognitive resource footprint.

4. Cognitive resource footprints

In order to exemplify the advantages of the above model we plotted a cognitive resource footprint of three distinct language processing tasks, shadowing, sight translation and simultaneous interpreting, in order to see if and to which extent the footprint relates to the inherent overall interference score as calculated using Wickens' [16] conflict matrix (figure 3).

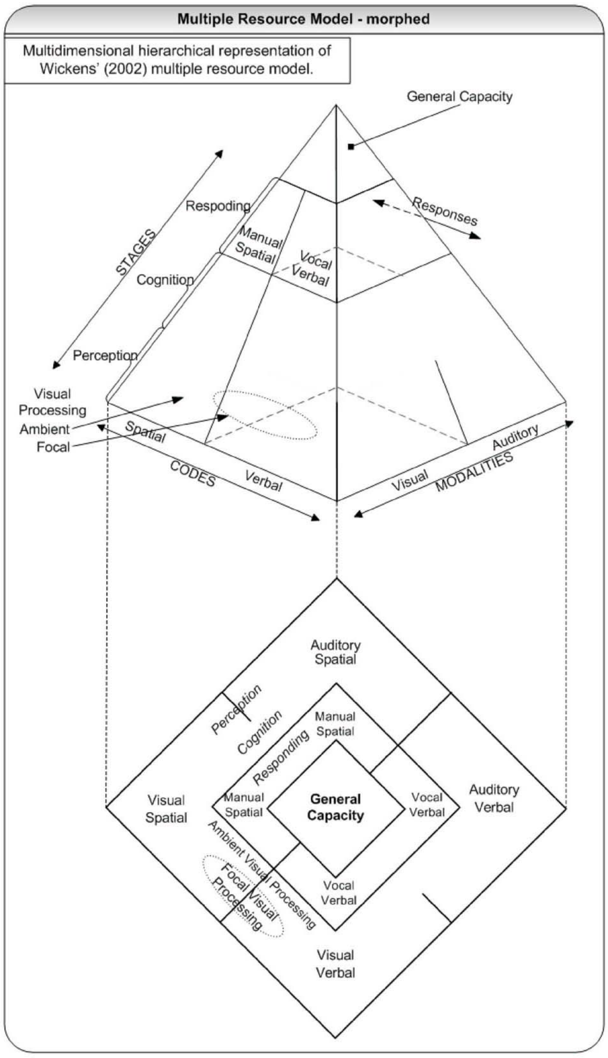

Figure 2: *Two-dimensional adaptation of the cube*

In this conflict matrix the maximal coefficient of interference between cognitive tasks is 1, whereas the demand vectors have an integer value (including Ø for no demand on a particular resource). In the schematic the demand vectors pertaining to the first task are plotted against the demand vectors pertaining to the second task. While the individual demand vectors are all chosen at 1, their respective point of intersection reveals the conflict coefficient. The maximum conflict coefficient is 1 and indicates the conflict between two tasks that cannot (physically) share a resource (e.g. two tasks requiring a verbal response). The baseline conflict coefficient on the other hand is 0.2, and reflects the "general capacity for which all tasks compete in a time sharing situation" [16:170]. With each dimension that is added to the task the coefficient increases by 0.2. The total interference score is then calculated by adding the sum of the demand vectors to the sum of the conflict coefficients. The main merit of the conflict matrix is not so much the possibility to calculate absolute interference scores, but rather to compare the outputs different task configurations yield. In the case at hand, for instance, the model predicts a higher total interference score for sight translation than for shadowing, and an even higher one for simultaneous interpreting.

Conflict Matrix

Adaptation of a typical conflict matrix based upon the three primary dimensions of the multiple resource model. Wickens (2002)

				task 1							
				perceptual				cognitive		response	
			vector	ø	ø	ø	ø	ø	ø	ø	ø
		demand		VISUAL SPATIAL	VISUAL VERBAL	AUDITORY SPATIAL	AUDITORY VERBAL	COGNITIVE SPATIAL	COGNITIVE VERBAL	RESPONSE SPATIAL	RESPONSE VERBAL
task 2	perceptual	ø	VISUAL SPATIAL	0.8	0.6	0.6	0.4	0.7	0.5	0.4	0.2
		ø	VISUAL VERBAL	0.6	0.8	0.4	0.6	0.5	0.7	0.2	0.4
		ø	AUDITORY SPATIAL	0.6	0.4	0.8	0.4	0.7	0.5	0.4	0.2
		ø	AUDITORY VERBAL	0.4	0.6	0.4	0.8	0.5	0.7	0.2	0.4
	cognitive	ø	COGNITIVE SPATIAL	0.7	0.5	0.7	0.5	0.8	0.6	0.6	0.4
		ø	COGNITIVE VERBAL	0.5	0.7	0.5	0.7	0.6	0.8	0.4	0.6
	response	ø	RESPONSE SPATIAL	0.4	0.2	0.4	0.2	0.6	0.4	0.8	0.6
		ø	RESPONSE VERBAL	0.2	0.4	0.2	0.4	0.4	0.6	0.6	1.0

Total interference score = demand vectors + conflict coefficients

Figure 3: *Conflict matrix*

4.1. Shadowing

Shadowing involves the repetition of a message delivered orally in one language in the same language. In terms of Wickens' conflict matrix (figure 3) this involves a first task recruiting auditory verbal resources at the perception and cognition stage co-occurring with a second task recruiting vocal verbal resources at the response stage. This is clearly illustrated in the cognitive resource footprint (figure 4) which shows the adjacent resources at the different stages. The overall interference score, calculated by adding the total of the demand vectors to the total conflict coefficients for the two tasks involved is 6.5.

4.2. Sight translation

Sight translation involves the transfer of a message written in one language into a message delivered orally in another language. As compared to shadowing, thus, the task can be argued to be cognitively more complex as it includes the element of transformation from one language into another whereas shadowing entails the verbatim repetition of the input [22, 23]. In terms of Wickens' conflict matrix, sight translation involves a first task recruiting visual verbal resources at the perception and cognition stage co-occurring with a task recruiting vocal verbal resources at the response stage, adding up to a total interference score of 8.8. The cognitive resource footprint (figure 5) shows how the shadowing task involves Wicken's fourth dimension, i.e. visual processing, which although it is conjectured to rely on a distinct resource pool contributes to a high interference score.

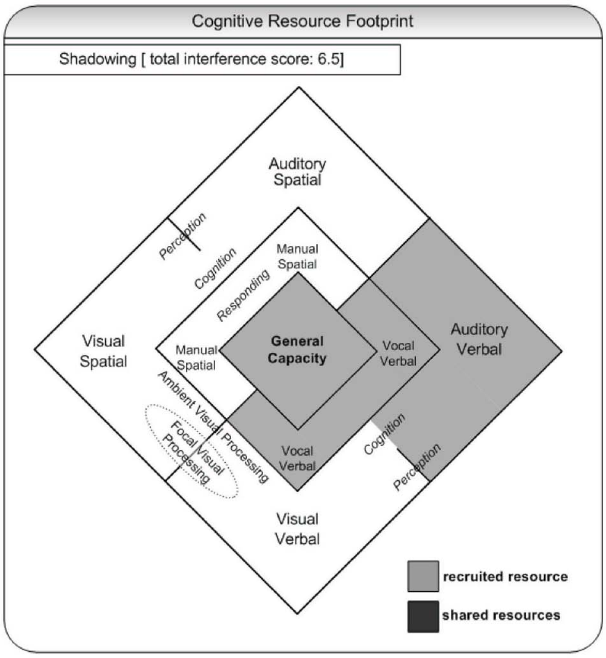

Figure 4: *Cognitive resource footprint: shadowing*

4.3. Simultaneous interpreting

Simultaneous interpreting, finally, involves the transfer of a message delivered orally in one language into a message delivered orally in another language. Its cognitive resource footprint (figure 6) is similar to that of shadowing, although auditory verbal resources at the cognition stage are recruited by the two co-occurring tasks, as the production of the output at any given time coincides with the processing of new input, resulting in a shared resource pool (shaded dark) and accounting for the highest overall interference score at 9.

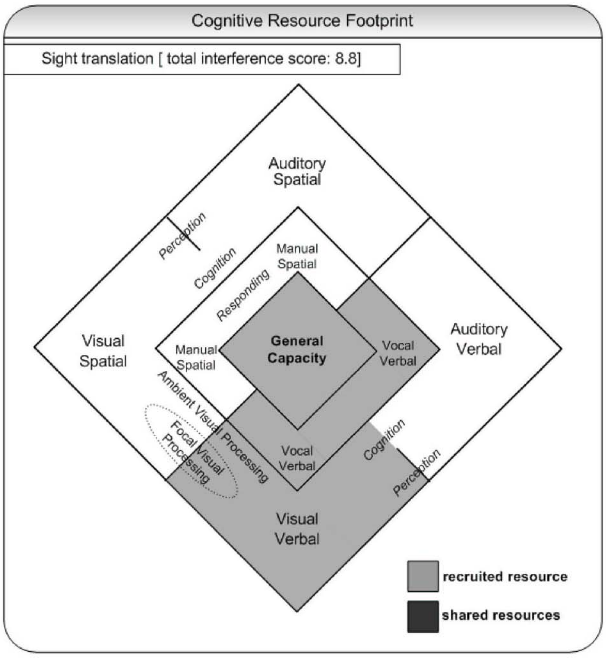

Figure 5: *Cognitive resource footprint: sight translation*

The cognitive resource footprints for the three tasks (figures 4, 5, 6) allow an intuitive understanding of the conflict potential inherent to them, and constitute a visual complement to the conflict matrix.

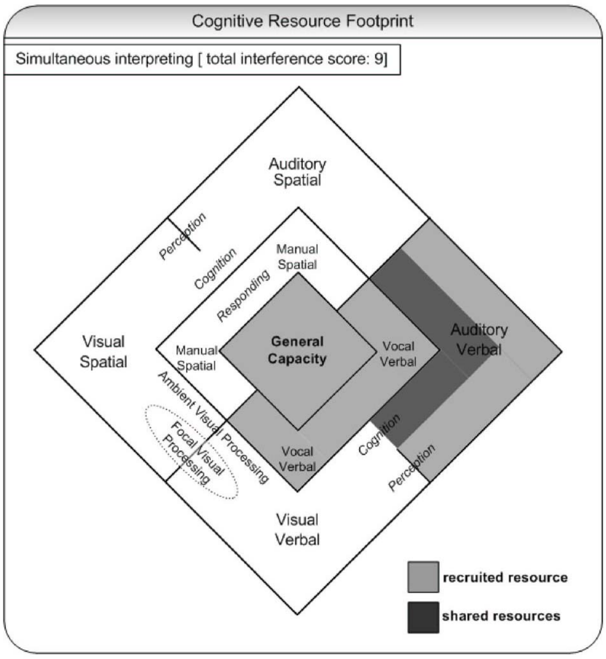

Figure 6: *Cognitive resource footprint: simultaneous interpreting*

5. Conclusions

The cognitive resource footprint was developed in order to compensate for the two primary shortcomings identified in Wickens' [2, 16] cube, i.e. its inability to visually account for the notion of general resources and the difficulty of visually representing the tasks and their proximity. The solution is a two dimensional model which can be used to complement Wickens' conflict matrix in order to easily identify the cognitive resources recruited during complex cognitive tasks.

6. References

[1] Wickens, C.D. (1980). The structure of attentional resources. In R. Nickerson (ed), Attention and performance VIII (pp 239-257). Hillsdale, NJ: Erlbaum.

[2] Wickens, C.D. (1984). Processing resources in attention. In R. Parasuraman, D.R. Davies (eds), Varieties of attention (pp.63-102). New York: Academic Press.

[3] Kahneman, D. (1973). Attention and Effort. Englewood Cliffs, NJ: Prentice-Hall.

[4] Alport, D.A., Antonis, B., Reynoldy, P. (1972). On the division of attention: A disproof of the single channel hypothesis. Quarterly journal of experimental psychology, 24: 225-235.

[5] Wickens, C.D., Gempler, K., Morphew, M.E. (2000).Workload and reliability of predictor displays in aircraft traffic avoidance. Transportation human factors journal, 2(2): 99-126.

[6] Wickens, C.D., Helleberg, J., Xu, X. (2002). Pilot Maneuver choice and workload in free flight. Human Factors, 44: 171-188.

[7] Young, M.S., Stanton, N.A. (1997). Automotive automation: investigating the impact on driver's mental workload. International journal of cognitive ergonomics, 1: 325-336.

[8] Gile, D. (1995). Regards sur la recherche en interprétation de conférence. Lille: Presses universitaires de Lille.

[9] Hyönä, J., Tommola, J., Alaja, A. (1995). Pupil dilation as a measure of processing load in simultaneous interpretation and other language tasks. The quarterly Journal of Experimental Psychology, 48A(3): 598-612.

[10] Lonsdale, D. (1997). Modeling cognition in SI: Methodological issues. Interpreting 2(1/2): 91-117.

[11] Massaro, D., & Shlesinger, M. (1997). Information processing and a computational approach to the study of simultaneous interpretation. Interpreting, 2(1/2): 13-53.

[12] Moser-Mercer, B. (1997). Beyond Curiosity. Can interpreting research meet the challenge? In J.H. Danks, S.B. Fountain, M.K. McBeath, G.M. Shreve (eds), Cognitive Processes in Translation and Interpreting. Applied Psychology: individual, social and community issues (pp.176-195). Thousand Oaks California: Sage Publishing.

[13] De Groot, A.M.B. (2000). A complex-skill approach to translation and interpreting. In S. Tirkkonen-Condit, R. Jääskeläinen (eds), Tapping and Mapping the processes of translation and interpreting (pp.53-68). Amsterdam: John Benjamins.

[14] Rinne, J.O., Tommola, J., Laine, M., Krause, B.J., Schmidt, D., Kaasinen, V., Teräs, M., Sipilä, H. & Sunnari, M. (2000). The translating brain: cerebral activation patterns during simultaneous interpreting. Neuroscience Letters, 294: 85-88.

[15] Gile, D. (1997). Conference Interpreting as a Cognitive Management Problem, in J. E. Danks, G.M. Shreve, S.B. Fountain, M.K. McBeath (eds), Cognitive Processes in Translation and Interpreting (pp 196-214). Thousand Oaks, London and New Delhi: Sage Publications.

[16] Wickens, C.D. (2002). Multiple resources and performance prediction. Theoretical issues in ergonomics science, 3(2): 159-177.

[17] Shallice, T., McLeod, P, Lewis, K. (1985). Isolation cognitive modules with the dual-task paradigm: Are speech perception and production modules separate? Quarterly journal of experimental psychology, 37: 507-532

[18] Baddeley, A.D., Lieberman, K. (1980). Spatial working memory and imagery mnemonics. In R. Nickerson (ed.), Attention and performance VIII (pp. 521-539). Englewook Cliffs, N.J.: Erlbaum.

[19] Wickens, C.D., Liu, Y. (1988). Codes and modalities in multiple resources: A success and a qualification. Human Factors, 30: 599-616.

[20] Seagull, F.J., Wickens, C.D., Loeb, R.G. (2001). When is less more? Attention and workload in auditory, visual and redundant patient-monitoring conditions. Proceedings of the 45th annual meeting of the Human Factors & Ergonomics Society.

[21] Previc, F.H. (1998). The neuropsychology of 3-D space. Psychological bulletin, 124: 123-164.

[22] Moser-Mercer, B. (1992). Sight translation and human information processing. In A. Neubert, G.M. Shreve, K. Gommlich (eds), Basic issues in translation studies. Proceedings of the fifth international conference. Kent Forum on Translation Studies, Volume II (pp. 195- 166). Ohio, Kent State University Press.

[23] Christoffels, I.K., De Groot, A.M.B. (2004). Components of simultaneous interpreting: Comparing interpreting with shadowing and paraphrasing. Bilingualism: Language and Cognition, 7: 227-240