Cognitive Psychology 77 (2015) 20–41

Contents lists available at ScienceDirect

Cognitive Psychology

journal homepage: www.elsevier.com/locate/cogpsych

Representing visual recursion does not require verbal or motor resources

Maurício de Jesus Dias Martins [a,b,c,d,*], Zarja Muršič [a], Jinook Oh [a], W. Tecumseh Fitch [a]

[a] Department of Cognitive Biology, University of Vienna, Althanstrasse 14, 1090 Vienna, Austria
[b] Berlin School of Mind and Brain, Humboldt Universität zu Berlin, Luisenstrasse 56, 10117 Berlin, Germany
[c] Max Plank Institute for Human Cognitive and Brain Sciences, Stephanstrasse 1a, 04103 Leipzig, Germany
[d] Language Research Laboratory, Lisbon Faculty of Medicine, Av. Professor Egas Moniz, 1649-028 Lisbon, Portugal

ARTICLE INFO

Article history:
Accepted 28 January 2015
Available online 2 March 2015

Keywords:
Hierarchy
Recursion
Self-embedding
Fractals
Language

ABSTRACT

The ability to form and use recursive representations while processing hierarchical structures has been hypothesized to rely on language abilities. If so, linguistic resources should inevitably be activated while representing recursion in non-linguistic domains. In this study we use a dual-task paradigm to assess whether verbal resources are required to perform a visual recursion task. We tested participants across 4 conditions: (1) Visual recursion only, (2) Visual recursion with motor interference (sequential finger tapping), (3) Visual recursion with verbal interference – low load, and (4) Visual recursion with verbal interference – high load. Our results show that the ability to acquire and use visual recursive representations is not affected by the presence of verbal and motor interference tasks. Our finding that visual recursion can be represented without access to verbal resources suggests that recursion is available independently of language processing abilities.

1. Introduction

Humans are exceptional creatures. Our ability to form complex social structures, and to transform our environment is unprecedented in the animal kingdom. What makes us exceptional is our cognitive

* Corresponding author at: Berlin School of Mind and Brain, Luisenstrasse 56, 10117 Berlin, Germany.
E-mail address: mauricio.martins@univie.ac.at (M. de J.D. Martins).

http://dx.doi.org/10.1016/j.cogpsych.2015.01.004

power: our ability to combine actions to achieve complex goals and to represent complex structures goes well beyond what is documented in any other animal species (Badre, 2008; Badre, Hoffman, Cooney, & D'Esposito, 2009; Conway, & Christiansen, 2001; Unterrainer, & Owen, 2006; Wohlschlager, Gattis, & Bekkering, 2003). Language, for example, requires the combination of words into sentences (Chomsky, 1957). The combinatorial processes involved in language are powerful and flexible, allowing us to generate an infinite number of meaningful sentences by combining a finite set of words (Hauser, Chomsky, & Fitch, 2002; von Humboldt, 1972).

Underlying the capacity to combine individual elements to form higher order structures is the concept of hierarchy. 'Hierarchy' can be used to denote a tree-like organization in structural representations where 'higher' levels incorporate multiple 'lower' levels. Language (Chomsky, 1957; Hauser et al., 2002), complex problem solving (Unterrainer, & Owen, 2006), and complex social navigation (Nardini, Jones, Bedford, & Braddick, 2008) all require the use and production of hierarchies (Fig. 1). For example, in action sequencing (Fig. 1C), the general goal of 'making coffee' is hierarchically superior, or 'dominant' over the specific actions of 'grinding the coffee beans' and 'filling the water container' (Jackendoff, 2002). Individuals can evaluate the need for these basic actions and omit them if they are unnecessary without impairing the overall procedure of making coffee (Badre, & D'Esposito, 2009).

Hierarchies can be generated and represented using processes that establish relationships of dominance and subordination between different items (Martins, 2012). Some of these processes are depicted in Fig. 2. For instance, 'iterative rules' (Fig. 2A) can be used to represent the successive addition of items to a structure, such as the addition of beads to a string to form a necklace. 'Embedding rules' can also be used to generate hierarchies by embedding one or more items into a structure so that they depend on another item (Fig. 2B). For example, in an army hierarchy, two brigades can be incorporated into a division. Finally, we can also use 'recursive embedding rules' to generate and represent hierarchies. Recursive embedding, or simply 'recursion', is the process by which we embed one or more items as dependents of another item of the *same category* (Fig. 2C). As we can see from Fig. 2,

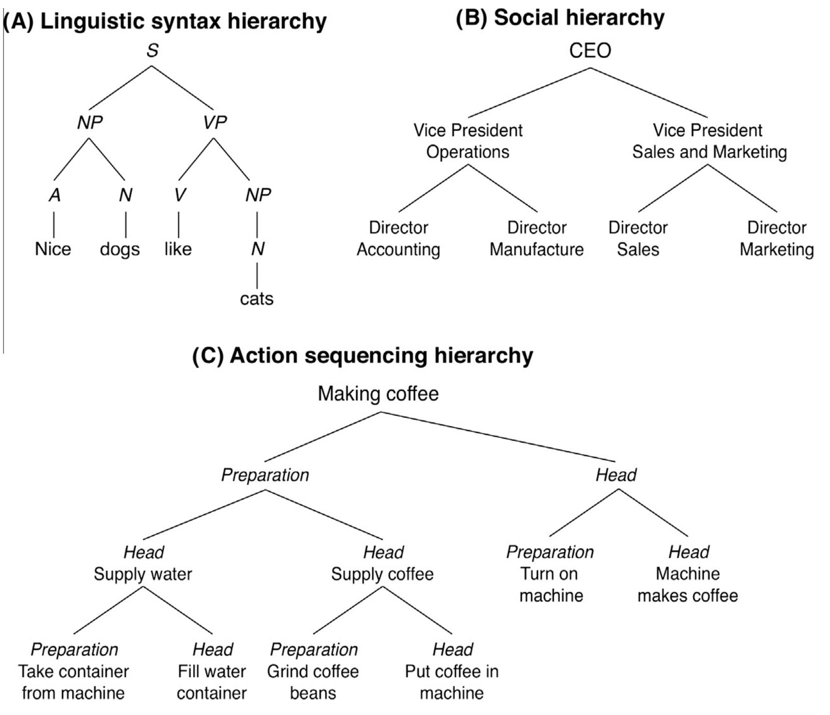

Fig. 1. Examples of linguistic (A), social (B) and action sequencing (C) hierarchies.