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Review

Cognitive

How developmental dissociations can inform cognitive theories

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Abstract

Introduction

The history of cognitive psychology is filled with examples of how theories of cognitive architecture can be informed by neuropsychological dissociations. This brief review shows that developmental dissociations, which occur when different effects appear diachronically in cognitive development, are also a valuable source of theoretical insights for cognitive psychology. However, similar to neuropsychological dissociations, developmental dissociations should also be treated cautiously, due to various methodological caveats (e.g. resource artefacts) that need to be taken into account when used to make inferences on normal cognitive processes. Even in the presence of these possible confounds, developmental dissociations may inspire new theories that should then be corroborated with additional, converging evidence. In one of the studies discussed in the review, for instance, it was suggested that different temporal preparation effects might depend on different cognitive systems, given that they followed different ontogenetic trajectories. This working hypothesis, which was initially inspired by a developmental dissociation, was then substantiated by means of various dissociative approaches in healthy adults and patients.

Conclusion

Dissociations in developmental trajectories may have a powerful heuristic value in generating novel testable hypotheses and providing information about cognitive functioning, not only in developmental stages but also in adulthood.

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Introduction

Developmental dissociations occur when different behavioural effects produced in one or more tasks are shown to appear diachronically in cognitive development, as revealed either longitudinally by testing the same group of individuals at different ages or, less ideally, cross-sectionally across different age groups. Many other authors have previously used the term 'developmental dissociation' both in clinical[1,2] and in non-clinical contexts[3,4].

Although it would be more likely to observe developmental dissociations in the context of disabilities, the present work focuses on the potential heuristic value of developmental dissociations as observed in non-clinical populations. The rationale underlying their use in cognitive neuroscience is analogous to that underlying dissociations in neuropsychology[5]: when two effects have different developmental trajectories, it is reasonable to hypothesise that they do not depend on the same system.

Discussion

The author has referenced some of his own studies in this review. These referenced studies have been conducted in accordance with the Declaration of Helsinki (1964) and the protocols of these studies have been approved by the relevant ethics committees related to the institution in which they were performed. All human participants, in these referenced studies, gave informed consent, or assent, together with their legal representative's consent in case of children, to participate in these studies.

Let us give an example of a simple developmental dissociation. Newborns rely on vowels to encode word forms, as suggested by differential activation in functional near-infrared spectroscopy[6], while children older than 1 year and adults prefer to use consonants for the same purpose[7]. These data demonstrate that children of different ages rely on different types of information, and possibly mechanisms, for encoding speech items.

The logic underlying developmental dissociations, however, is weakened by the same caveats that apply to neuropsychological dissociations obtained in lesion patients or healthy individuals undergoing temporary disruptive stimulation such as transcranial magnetic stimulation (TMS) or transcranial direct current stimulation.

We will start with the most important caveat concerning resource artefacts[5]. Suppose that two behavioural effects A and B start to emerge at different ages, with the effect A appearing some years before the effect B. It can be inferred that the process underlying the effect A requires neurocognitive mechanisms that mature earlier than that underlying the effect B. However, it is in fact possible to interpret this single developmental dissociation as due to a resource artefact: the process underlying the two effects may be the same, but these effects need different levels of general processing resources. The processing resources available to young children may suffice for the effect A to appear, but they may be inadequate for the effect B, which would appear when maturation will make

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Review

more resources, such as enhanced basic perceptual and motor processes or strategies, available[4]. In the above example[6], a resource artefact account is very likely to explain the data. The immature perceptual system of newborns would more easily encode (and remember) vowels than consonants, given that the former produce a greater amount of energy than the latter (vowels being louder and lasting longer than consonants), while to rely on the more informative but less salient consonants to encode words would require a more mature auditory system.

This caution should be taken in serious consideration when inferences are drawn from a developmental dissociation. One way to partially overcome this problem is to check whether there is a double dissociation with data obtained from older children or adults. A double dissociation would occur when (i) a behavioural effect A is present in younger children and another effect B is absent or present at a smaller extent and (ii) the effect A is relatively less pronounced than the effect B in older subjects (contrary to what happens in younger children). In the presence of a double dissociation, accounting for the developmental pattern in terms of an artefact of resources is likely to be inappropriate, since this would not fit with the presence of the more demanding effect B in the absence of the less demanding effect A in the older sample. One could still suppose that the process underlying the effect B acts by attenuating that underlying the effect A. However, this testable assumption still implies that the two effects are due to two distinct albeit interacting mechanisms.

Although an age-dependent double dissociation is unlikely to occur, it has occasionally been found. Davidson et al.[8] found exactly this pattern. In their study, different executive function tasks were administered to children from 4 to 13 years of age and to young adults. Younger children and adults showed a double dissociation. In children, performance on a cognitive flexibility task (i.e. switching between rules) was more impaired than performance on a working memory task (with increasing working memory load). For adults, the working memory task was relatively more difficult than the cognitive flexibility task. In that case, it was not possible to interpret the impairment of children in the cognitive flexibility task as due to the fact that it was generally more difficult than the working memory task. This hypothesis is indeed disconfirmed by the fact that adults found the working memory task relatively more difficult than the cognitive flexibility task. On the other hand, it is possible to assume that the cognitive flexibility task was more impaired in youngest children tested in that study because the frontoparietal network and related processes critical for this task[9,10] were not yet fully developed in that age group.

Another important interpretational caution derives from the observation that double dissociations per se do not warrant the existence of different modules[5,11]. Computational modelling has extensively demonstrated that it is possible to obtain double dissociations in both mature (adult) and developmental (children) systems by simply lesioning different portions of a single integrated mechanism[12–15]. Therefore, the observation of a developmental dissociation, even if in the form of a more 'elegant' double dissociation, should be taken as tentative and needs to be corroborated by more convincing evidence of the existence of different modules originating from some other methods.

Nevertheless, even when a pattern of age-related double dissociation is not found or, if found, does not warrant the existence of different modules, the heuristic value of developmental dissociations in testing and generating specific hypotheses still holds. As a first example, I would like to present some data concerning the variable foreperiod (FP) phenomena. When the preparatory period (FP) between a warning and a target stimulus is randomly but equiprobably administered from a range of possible FPs, two basic phenomena occurs: response times are longer as the current FP increases (FP effects) and as the preceding FP increases (sequential effects).

In a developmental study of preparation over time[16], the specific models to be tested were a trace conditioning single-process account[17] and strategic dual-process accounts[18] of the FP and the sequential effects. It should be noted that neither of these accounts predicts that the FP effect and the sequential effects differ substantially on the required resources.

On the conditioning view, the resources necessary for the two effects should be identical, just because the two effects are supposedly due to the same conditioning mechanism: repeating a FP reinforces the preparatory level associated to it, whereas overcoming a FP with a longer one during a trial extinguishes its associated preparatory level (see Los and van den Heuvel[17] for details).

On the classical strategic view[18], people expect a repetition of FPs from one trial to the next one and, if this repetition does not occur, they can strategically re-prepare (or maintain preparation over time) when an expected short FP is overcome by a longer one. Note that since these strategic views assume that the two processes underlying the FP phenomena (FP repetition expectation and maintenance/re-preparation) are both strategic, there is no evident reason why these two processes should dramatically differ in the amount of the resources required.

Two opposite predictions about the developmental time course of the two effects could be derived from these two accounts. A parallel development of the two effects was

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expected by the conditioning view given that it claims that they rely exactly on the same mechanism. The strategic view would predict no interaction during early developmental stages, or if one mechanism (FP repetition expectancy) occurs without the other (re-preparation/maintenance), a crossover interaction between current and preceding FPs (i.e. faster Response Times for short–short and long–long FP sequences than for long–short and short–long ones).

Neither of these patterns was observed, since parallel sequential effects were found in 4-year-old children in the absence of a current FP effect: response times were longer for both short and long current FPs when the preceding FP was long than when it was short. Therefore, the developmental dissociation approach was useful to disconfirm two hypotheses and to put forward a new testable double-process hypothesis: the FP effect is due to more controlled, prefrontally dependent mechanisms, while more automatic, premotor-based mechanisms produce sequential effects. This model was then corroborated by means of other more traditional dissociative methodologies, such as dual-task interference[19] or neuropsychological[20], TMS[21] and functional magnetic resonance imaging dissociations[22].

As another example, the author presents a developmental study on a dimensional change card-sorting test[23]. Children of different ages were asked to sort a series of bivalent test cards according to one of two dimensions (e.g. colour or shape). After a certain amount of practice, they were required to sort cards according to the other dimension. Three-year-old children did not switch to the other dimension and perseverated on the first one[4,24,25]. When explicitly asked about the post-switch rules, children demonstrated that they had understood them. Thus, a dissociation occurred between two levels of consciousness in these young children: rule knowledge (present) and rule implementation (absent). A single consciousness system was hypothesised by early information-processing models[26,27]. However, the developmental data discussed above suggest that there may be several levels of consciousness progressively accessible at different developmental stages[28].

Although initially proposed to explain developmental data, this model could potentially hold in adulthood as well. One example is anosognosia, the incapacity to recognise one's own deficit in performing a task although the task rules are perfectly known. This cognitive syndrome occurs after damage to certain brain regions, such as the right parietal lesions underlying neglect or pre-motor damage underlying hemi-paresis. A similar dissociation between knowledge and behaviour is frequent with frontal lobe lesions[29,30]. The same dissociations also occur in healthy adults in conditions with effortful processing and increasing task rules[31]. It has been observed that, albeit adult individuals are able to correctly describe different task components, they do not actually implement one component when performing a complex task, a phenomenon called 'goal neglect'[32].

Many other studies have reported potential differences in the developmental trajectory of various executive functions[33–37], thus indirectly favouring models that suggest a fractionation of executive functions[38–40] over those that propose a more unitary view[41].

Not only could the presence of a developmental dissociation but also its absence sometimes be revealing. As an example, there are suggestions that space and time processing develop together, which derive from studies investigating analogous magnitude processing in animals and children[42], and from neuropsychological findings showing that the same critical regions are devoted to the processing of spatial, temporal and quantity information[43]. This evidence inspired a model, A Theory of Magnitude (ATOM)[44] according to which space, time and numbers are all represented by a common magnitude system. This model in its first version implies a symmetric interference when information coming from one domain is conflicting with information belonging to the other. However, a recent study found that even kindergarten children have asymmetric interference from space to time, but not vice versa, an effect that does not change with age (i.e., absence of developmental dissociation), suggesting that the spatial prevalence over time is robust to maturation[45] and pushing towards a refinement of the ATOM model.

Another potentially confounding factor to consider in developmental dissociations is practice or frequency of exposure. In language acquisition, for instance, frequency may play a role as to when a particular syntactic construction is acquired. The frequency of errors in producing irregular past tenses in English is positively correlated, among other factors, with word frequency[46]. Another example in this respect comes from a study by Carlesimo et al.[47]. This study focused on verbal repetition priming, which was operationalised as a response time advantage in completing fragments to form words that have been previously encountered and implicitly encoded than in completing fragments using new words. Two contrasting theories account for this effect by supposing that it originates either (i) from re-activation of previously established long-term memory representations in the input lexicon or (ii) from the formation of new episodic memory traces when the word is first encountered in the experimental context.

Children represent an ideal experimental model to test these two theories. They acquire the auditory

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word lexicon before the written word lexicon, which is only acquired when they learn how to read. The two accounts of verbal repetition priming predict different developmental trajectories for auditory and visual verbal repetition priming. The re-activation theory predicts a developmental dissociation between auditory priming, which should occur earlier since children are likely to have been auditorily exposed several times to words, and visuo-verbal priming, which should instead occur later, that is only after acquisition of the written language. On the episodic account, instead, no such a difference is expected. Carlesimo et al.[47] administered an auditory and a written version of the verbal repetition priming task to Italian first-, third- and fifth-graders. A developmental dissociation was observed between auditory priming, which was not influenced by age, and visual priming, which increased linearly with age and with a measure of lexicality in reading (but see Naito[48], for negative evidence in Japanese children).

The authors interpreted these findings as supporting the hypothesis that repetition priming for words originates from facilitated access to pre-existing memory representations. However, an alternative explanation derives from the resource artefact issue. Reading words is conceivably much more demanding and inefficient for first-graders than for fifth-graders, since the former have not yet fully acquired this skill. Younger children may not encode new memory traces for the words just read as efficiently as older children, thus explaining the different developmental trajectories of repetition priming in the two different modalities with the fact that, not only long-term representations, but even the short-term representations of written words are poorer in younger children.

An additional caveat concerning developmental dissociations is that an overt behavioural effect might assume different meanings and underlie different neurocognitive mechanisms, whether it occurs in younger children or in older children and in adults. Houdé et al.[49] used a pointing task where participants of different age groups (5–9 years) had to discover a rule of alternation between two locations. The youngest children (5–6 years old) discovered the alternation rule much earlier than older children. The latter used a (slower) trial-and-error strategy to discover the rule. Could we assume from this pattern of data that younger children are strategically superior to older ones? An earlier neuropsychological study offers an alternative explanation. This study showed that patients with lesions in the lateral prefrontal cortex behaved similarly to the youngest children in Houdé et al.'s study[49], performing better than controls. Their success on this task was probably not due to a better strategic capacity of using the feedback to adjust behaviour than healthy controls. It is much more likely that prefrontal patients, and young children with immature prefrontal cortex, succeeded in this task as a side-effect of their well-known failure to suppress a pre-potent tendency to explore the environment[50], thus non-strategically producing the alternation behaviour.

Conclusion

The evidence presented here demonstrates that developmental dissociations are a valuable tool not only for developmental psychologists but also for cognitive neuroscience in general. Developmental dissociations, although they have many methodological caveats that should be taken into consideration when used to make inferences on normal cognitive processes, have a powerful heuristic value in producing new working hypotheses and advancing neuroscientific knowledge.

Abbreviations list

ATOM, A Theory of Magnitude; FP, foreperiod; TMS, transcranial magnetic stimulation; RTs, Response Times.

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References

1. Capute AJ, Palmer FB. A pediatric overview of the spectrum of developmental disabilities. J Dev Behav Pediatr. 1980 Jun;1(2):66–9.
2. Voigt RG, Barbaresi WJ, Colligan RC, Weaver AL, Katusic SK. Developmental dissociation, deviance, and delay: occurrence of attention-deficit-hyperactivity disorder in individuals with and without borderline-to-mild intellectual disability. Dev Med Child Neurol. 2006 Oct;48(10):831–5.
3. Defeyter MA, Hearing J, German TC. A developmental dissociation between category and function judgments about novel artifacts. Cognition. 2009 Feb;110(2):260–4.
4. Murphy K, McKone E, Slee J. Dissociations between implicit and explicit memory in children: the role of strategic processing and the knowledge base. J Exp Child Psychol. 2003 Feb;84(2):124–65.
5. Shallice T. From neuropsychology to mental structure. Cambridge: Cambridge University Press; 1988.
6. Benavides-Varela S, Hochmann JR, Macagno F, Nespor M, Mehler J. Newborn's brain activity signals the origin of word memories. Proc Natl Acad Sci U S A. 2012 Oct;109(44):17908–13.
7. Hochmann JR, Benavides-Varela S, Nespor M, Mehler J. Consonants and vowels: different roles in early language acquisition. Dev Sci. 2011 Nov;14(6):1445–58.
8. Davidson MC, Amso D, Anderson LC, Diamond A. Development of cognitive control and executive functions from 4 to

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All authors abide by the Association for Medical Ethics (AME) ethical rules of disclosure.

13 years: evidence from manipulations of memory, inhibition, and task switching. Neuropsychologia. 2006;44(11): 2037–78.
9. Bode S, Haynes JD. Decoding sequential stages of task preparation in the human brain. Neuroimage. 2009 Apr;45(2): 606–13.
10. Braver TS, Reynolds JR, Donaldson DI. Neural mechanisms of transient and sustained cognitive control during task switching. Neuron. 2003 Aug;39(4):713–26.
11. Warrington EK, McCarthy RA. Categories of knowledge. Further fractionations and an attempted integration. Brain. 1987 Oct;110(Pt 5):1273–96.
12. Farah MJ, McClellan JL. A computational model of semantic memory impairment: modality specificity and emergent category specificity. J Exp Psychol Gen. 1991 Dec;120(4):339–57.
13. Joanisse MF, Seidenberg MS. Impairments in verb morphology after brain injury: a connectionist model. Proc Natl Acad Sci U S A. 1999 Jun;96(13): 7592–7.
14. Plaut DC. Double dissociation without modularity: evidence from connectionist neuropsychology. J Clin Exp Neuropsychol. 1995 Apr;17(2):291–321.
15. Thomas M, Karmiloff-Smith A. Are developmental disorders like cases of adult brain damage? Implications from connectionist modelling. Behav Brain Sci. 2002 Dec;25(6):727–50.
16. Vallesi A, Shallice T. Developmental dissociations of preparation over time: deconstructing the variable foreperiod phenomena. J Exp Psychol Hum Percept Perform. 2007 Dec;33(6): 1377–88.
17. Los SA, van den Heuvel CE. Intentional and unintentional contributions to nonspecific preparation during reaction time foreperiods. J Exp Psychol Hum Percept Perform. 2001 Apr;27(2): 370–86.
18. Alegria J. Sequential effects of foreperiod duration: Some strategical factors in tasks involving time uncertainty. In Rabbit P, DornicS,editors. Attention and performance. London: Academic Press; 1975;5.pp.1–10.
19. Vallesi A, Arbula S, Bernardis P. Functional dissociations in temporal preparation: evidence from dual-task performance. Cognition. 2014 Feb;130(2): 141–51.
20. Vallesi A, Mussoni A, Mondani M, Budai R, Skrap M, Shallice T. The neural basis of temporal preparation: insights from brain tumor patients. Neuropsychologia. 2007 Sep;45(12):2755–63.
21. Vallesi A, Shallice T, Walsh V. Role of the prefrontal cortex in the foreperiod effect: TMS evidence for dual mechanisms in temporal preparation. Cereb Cortex. 2007 Feb;17(2):466–74.
22. Vallesi A, McIntosh AR, Shallice T, Stuss DT. When time shapes behavior: fMRI evidence of brain correlates of temporal monitoring. J Cogn Neurosci. 2009 Jun;21(6):1116–26.
23. Zelazo PD, Frye D, Rapus T. An age-related dissociation between knowing rules and using them. Cogn Dev. 1996 Jan;11(1):37–63.
24. Diamond A, Carlson SM, Beck DM. Preschool children's performance in task switching on the dimensional change card sort task: separating the dimensions aids the ability to switch. Dev Neuropsychol. 2005;28(2):689–729.
25. Morton JB, Munakata Y. Active versus latent representations: a neural network model of perseveration, dissociation, and decalage. Dev Psychobiol. 2002 Apr;40(3):255–65.
26. Moscovitch M. Confabulation and the frontal systems: strategic versus associative retrieval in neuropsychological theories of memory. In: Roediger HL, Craik FIM, editors. Varieties of memory and consciousness: essays in honour of Endel Tulving. Hillsdale, NJ, England: Lawrence Erlbaum; 1989.pp.133–60.
27. Schacter DL. On the relation between memory and consciousness: dissociable interactions and conscious experience. In: Roediger HL, Craik FIM, editors. Varieties of memory and consciousness: essays in honour of Endel Tulving. Hillsdale, NJ, England: Lawrence Erlbaum; 1989.pp.355–89.
28. Zelazo PD. The development of conscious control in childhood. Trends Cogn Sci. 2004 Jan;8(1):12–7.
29. Luria AR. Human brain and psychological processes. New York, NY: Harper and Row.
30. Milner B. Effects of different brain lesions on card sorting: the role of the frontal lobes. Arch Neurol. 1963 Jul;9(1):90–100.
31. Duncan J. The multiple-demand (MD) system of the primate brain: mental programs for intelligent behaviour. Trends Cogn Sci. 2010 Apr;14(4):172–9.
32. Duncan J, Emslie H, Williams P, Johnson R, Freer C. Intelligence and the frontal lobe: the organization of goal-directed behavior. Cogn Psychol. 1996 Jun;30(3):257–303.
33. Casey BJ, Tottenham N, Liston C, Durston S. Imaging the developing brain: what have we learned about cognitive development? Trends Cogn Sci. 2005 Mar;9(3):104–10.
34. Crone EA, Ridderinkhof KR, Worm M, Somsen RJM, van der Molen MW. Switching between spatial stimulus-response mappings: a developmental study of cognitive flexibility. Dev Sci. 2004 Sep;7(4):443–55.
35. Diamond A, Kirkham N, Amso D. Conditions under which young children can hold two rules in mind and inhibit a prepotent response. Dev Psychol. 2002 May;38(3):352–62.
36. Perner J, Sprung M, Steinkogler B. Counterfactual conditionals and false belief: a developmental dissociation. Cogn Dev. 2004 Apr–Jun;19(2):179–201.
37. Zelazo PD, Craik FIM, Booth L. Executive function across the life span. Acta Psychol. 2004 Feb–Mar;115(2–3): 167–83.
38. Shallice T. The fractionation of supervisory control. In :MSGazzaniga (Ed.), The cognitive neurosciences. 3rd ed. Cambridge, MA: MIT Press; 2004.pp. 943–56.
39. Stuss DT, Alexander MP. Is there a dysexecutive syndrome? Philos Trans R Soc Lond B Biol Sci. 2007 May;362 (1481):901–15.
40. Vallesi A. Organization of executive functions: hemispheric asymmetries. J Cogn Psychol. 2012;24(4):367–86.
41. Duncan J, Owen AM. Common regions of the human frontal lobe recruited by diverse cognitive demands. Trends Neurosci. 2000 Oct;23(10):475–83.
42. Gallistel CR, Gelman I. Non-verbal numerical cognition: from reals to integers. Trends Cogn Sci. 2000 Feb;4(2):59–65.
43. Basso G, Nichelli P, Frassinetti F, di Pellegrino G. Time perception in a neglected space. Neuroreport. 1996 Sep;7(13):2111–4.
44. Walsh V. A theory of magnitude: common cortical metrics of time, space and quantity. Trends Cogn Sci. 2003 Nov;7(11):483–8.

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All authors abide by the Association for Medical Ethics (AME) ethical rules of disclosure.

45. Casasanto D, Fotakopoulou O, Boroditsky L. Space and time in the child's mind: evidence for a cross-dimensional asymmetry. Cogn Sci. 2010 Apr;34(3):387–405.
46. Marchman VA. Children's productivity in the English past tense: the role of frequency, phonology, and neighborhood structure. Cogn Sci. 1997 Jul;21(3):283–304.
47. Carlesimo GA, Vicari S, Albertoni A, Turriziani P, Caltagirone C. Developmental dissociation between visual and auditory repetition priming: the role of input lexicons. Cortex. 2000 Apr;36(2):181–93.
48. Naito M. Repetition priming in children and adults: age-related dissociation between implicit and explicit memory. J Exp Child Psychol. 1990 Dec;50(3):462–84.
49. Houdé O, Angeard N, Pillon B, Dubois B. A new window on child prefrontal functions: inhibition of a non-strategic alternation-pointing scheme. Curr Psychol Lett Behav Brain Cogn. 2001;5(2):49–63.
50. Lhermitte F. 'Utilization behaviour' and its relation to lesions of the frontal lobes. Brain. 1983 Jun;106(Pt 2):237–55.

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