From mean level changes to intraindividual variability

Inter- and intraindividual variability across the lifespan

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Development and intraindividual variability (IIV)

- Developmental psychology has focused almost exclusively on the average level of performance. Variability (both inter- and intraindividual) has been considered as « noise », or, at best, as quantitative variations around a same norm (possibly useful from the standpoint of application); cf also Ghisletta's talk: variability is THE interesting point to focus on

- **« The study of intraindividual variability is fundamental for the comprehension of interindividual differences and of developmental change»** (John Nesselroade, 1991)
- Yet …

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Why is it necessary to study individual variability rather than only average performance?

- Obvious that individuals vary greatly from each other, and in their own behavior across occasions and situations
- Other disciplines have insisted on the importance of variability (physics, biology, etc.), so why shouldn't variability be crucial as concerns one of the most complex systems to be studied?
- Number of empirical demonstrations in the last decades that a picture of development in terms of a universal trend leads to gross oversimplifications

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Why is it necessary to study variability? (ctd)

- Has been shown to be a predictor, complementary to mean level of performance, of later cognitive decline or of resilience (not all variability is maladaptive – e.g., Siegler's study of strategies in children)
  cf Hultsch et al: variability was relative stable, and could differentiate demented patients from healthy and arthritis controls
- Can help uncovering differences between children and older adults when mean level is similar
- Has been shown to present neural covariates
  e.g., difference between young and older adults in functional interconnections; dedifferentiation of cerebral areas, compensation (e.g. Cabeza; Park)
- Has been shown to help testing the hypothesis of differentiation-dedifferentiation across the lifespan = old hypothesis that has regained popularity

Why is variability so little studied?

Individual differences are very important at all ages, but particularly in older adulthood; yet they are little studied. Why?

- Methodological problems: difficult to disentangle individual variability from mean level, both at the group and the intra-individual level
  => Question = how best to describe individual differences?
- Constant confounding between inter-individual and intra-individual variability, e.g.,:
  - Age differences observed in cross-sectional studies have been interpreted as intra-individual change, in most developmental studies. But demonstration of large differences between longitudinal and cross-sectional studies (e.g., Seattle Longitudinal Study)
  - Between-task correlations often interpreted as index of intra-individual variability. But show structure of interindividual differences across tasks

Hypothesis of differentiation-dedifferentiation with age

Most comprehensive hypothesis about lifespan change in variability: organization of behaviors unfolds from childhood to adulthood, and contracts again in older adulthood (Garrett, 1946; Reinert, 1970; Cattell, 1971; Baltes, Lindenberger, & Staudinger, 1998)

Differentiation from childhood to adulthood:

- Increase in the number of factors needed to account for individual differences in intelligence
- Decrease in the variance accounted for by a general factor (*g*) and increase in the variance accounted for by specific factors

Dedifferentiation during adulthood (particularly older adulthood):

- Increase in the variance accounted for by *g*
- Decrease in the number of factors

⇒However, some controversy (e.g., Morse, 1993)

⇒Moreover, based on correlational designs=> confound of inter- and intra-individual differences

Types of individual variability

- Interindividual (Between-subject) variability = **Diversity**
  - Seems higher in older adults (Morse, 1993; Nelson & Dannefer, 1992). But often studied with RT's => higher means in older adults => higher standard deviations
  - Very few studies with children; could be higher in children than in young adults, but not necessarily, given the importance of "universals"
- Short-term (within-task) intra-individual variability, «**inconsistency** » (Hultsch et al., 2004); processing robustness, lability, etc) = fluctuations across trials, more or less reversible, from trial to trial or when the task is repeated with a short interval;
- Intra-individual variability across different tasks = **dispersion**
  - it has long been erroneously considered that such IIV could be studied with correlations. However, correlations indicate structure of interindividual variability: A weak corelation indicates that individuals are not classified (ranked) similarly by the various tasks. It shows that tasks rely on different processes, but does not necessarilty imply that that IIV is important. Only an analysis of intra-individuals profiles (patterns) can provide information about dispersion;
- Intra-individual variability on a longer term. Reflects more or less durable **intra-individual change**;longitudinal study, learning study.

Intra-individual variability across the Lifespan

In Hultsch & MacDonald, (2004)

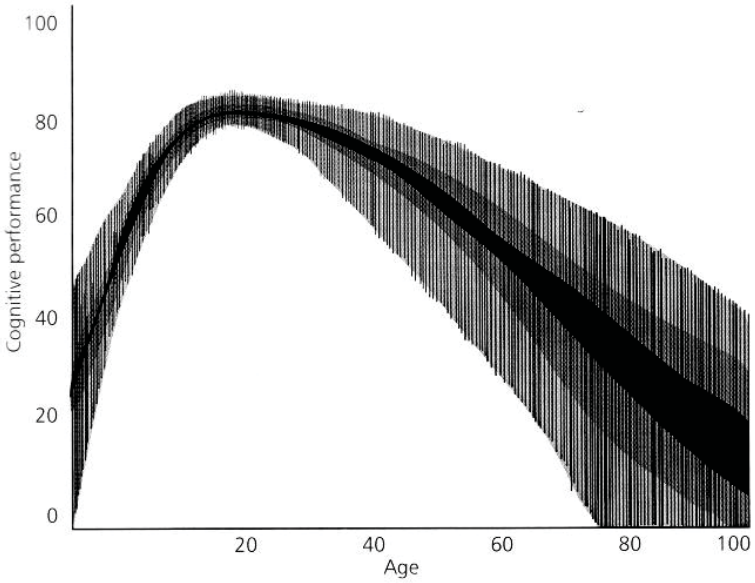


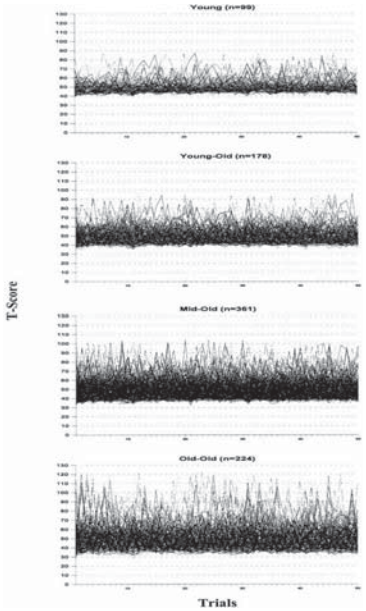
Fig. 4.4 Hypothetical confluence of lifespan trajectories for intraindividual variability and intraindividual change in cognitive performance.

Could also be used to depict interindividual variability

What kind of empirical evidence?

1. IIV as inconsistency : Hultsch et al. The example of the Geneva Variability Study (GVS)
2. IIV as dispersion: The example of the Wechsler scales
3. IIV as intraindividual change: Schaie's longitudinal study (cf Introduction to the workshop)
4. IIV in the brain
   - Intraindividual change: Raz' studies
   - Inconsistency: McIntosh et al.

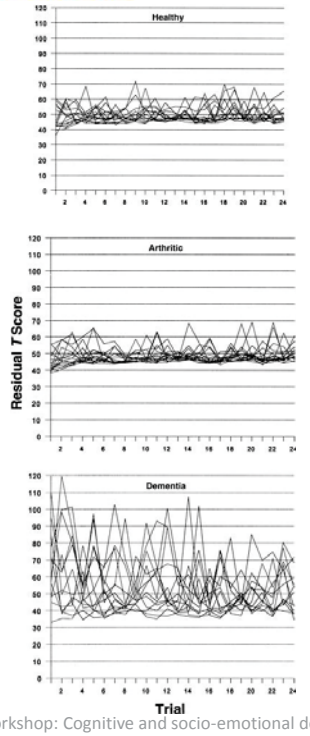
What kind of empirical demonstration? - ctd



Simple reaction time residual latency T scores by trial (purified for age, gender, and trial effects) for each participant graphed separately by age group.

David F. Hultsch et al. J Gerontol B Psychol Sci Soc Sci 2002;57:P101-P115

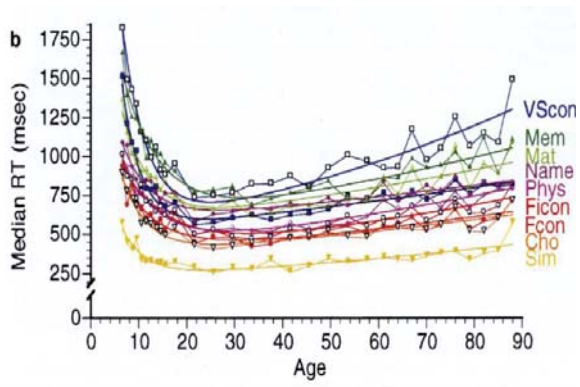
What kind of empirical demonstration? - ctd



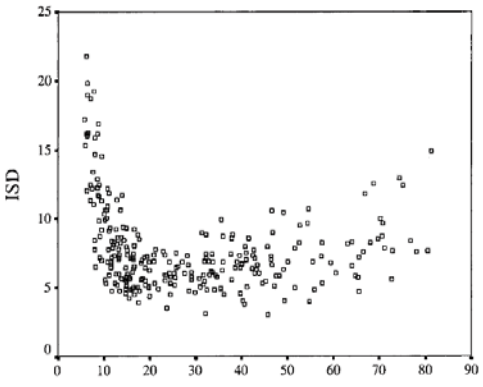
Intraindividual variability in cognitive performance in older adults: Comparison of adults with mild dementia, adults with arthritis, and healthy adults.

Hultsch, MacDonald, Hunter, Michael A, Levy-Bencheton, & Strauss. Neuropsychology, 2000.

Inconsistency across development - ctd



Li et al. 2004. Figure 1C: lifespan age gradients of fluid intelligence, crystallized intelligence, processing speed, and processing robustness (composite of standard deviations of the trial RTs for all the BECTs; reflected so that a higher score signified relatively small intraindividual trial-by-trial RT fluctuations in all the BECTs.) .



Williams et al., Neuropsychology 2005, 19,1. Figure 2. Scatter plot of inconsistency (intraindividual standard deviation [ISD] of residualized choice reaction time) across the life span.

Inconsistency: What kind of empirical demonstration? - ctd

In children, observed in ADHD children

(Borella, Chicherio, Re, Sensini, & Cornoldi, 2011; Castellanos & Tannock, 2002; Kunsti, Oosterlaan, & Stevenson, 2001; Leth-Steensen, Elbaz, & Douglas, 2000; Steger et al., 2001).

Borella, de Ribaupierre, Cornoldi & Chicherio, 2013:

> *In sum, findings on both mean RTs and IIV clearly do not converge with theories suggesting the existence of a specific deficit, in children with ADHD, in the control of interference in the Color-Stroop test. Interference control may, thus, be a less fundamental characteristic of the disorder than previous empirical work led researchers to believe. Nonetheless, the present data are consistent with difficulties involving a self-regulatory deficit or a failure to allocate adequate effort to meet task demands in children with ADHD, as suggested by Douglas (1999); this deficit leads to some extent to the occurrence of a higher number of attentional lapses during the course of information processing, as shown by IIV indices*

Inconsistency - summary

More important in pathological groups, and in older adults or children (ADHD) (e.g. Kälin, et al., 2014; Burton et al., 2003; Hultsch et al., 2000; Dixon et al., 2007; Hill et al., 2013)

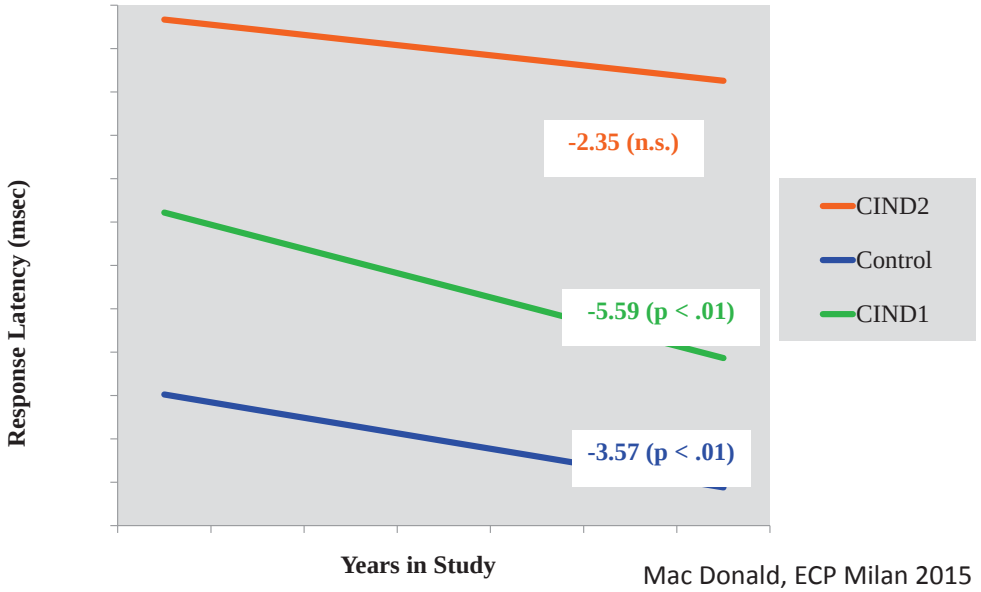
► Link between IIV and moment of death (MacDonald et al., 2008)

► IIV predicts early dementias (Cherbuin et al., 2010), and subsequent cognitive decline (Bielak, et al., 2010)

► In chidren, observed in ADHD

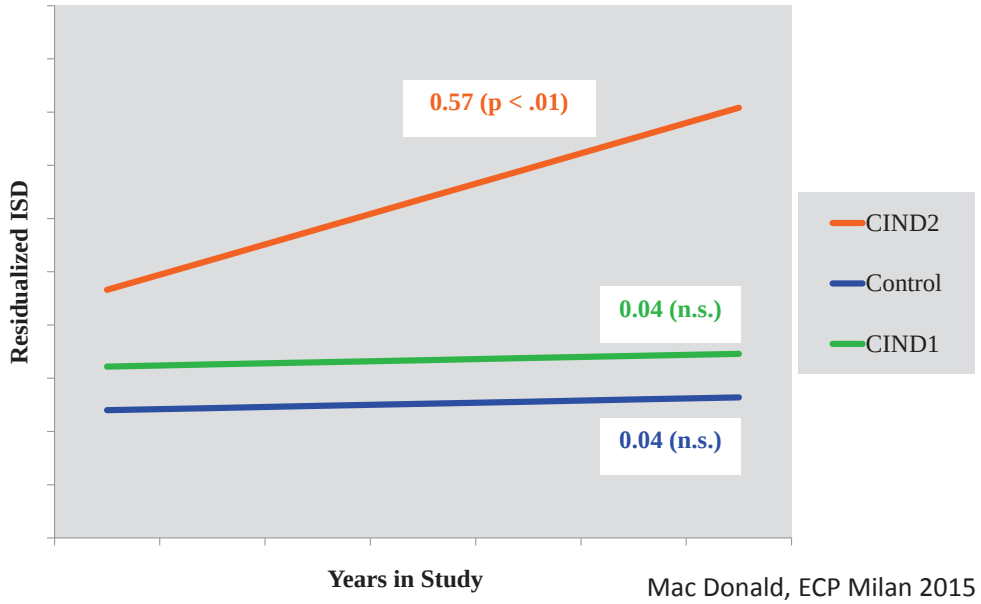
Does inconsistency provide a different view?

6-Year Change in CRT Mean



Mac Donald, ECP Milan 2015

6-Year Change in CRT Variability (RTI)



Mac Donald, ECP Milan 2015

Dispersion: Wechsler and intraindividual variability

1. Standardized scales, mean = 10, standard deviation= 3
2. Profiles analyses since Kaufman's studies (1979)
3. Integration of some analyses in clinical practice: « intuitive » estimation by applied psychologists of the range between minimal and maximal standard score ≅ 3-4 points

WISC IV (In Grégoire, 2009):

Range (difference between minimal and maximal score): mean= 7.5, SD = 2.3

Depends on global level:

QI total	étendue	écart-type
120-	7.2	2.1
110-119	7.2	2.4
90-109	7.6	2.4
80-89	7.6	2.4
-79	8.1	2.1

Grégoire, 2009, Table 51

Even though subtests are all standardized, the rule at the intraindividual level is an important difference between highest and lowest scores => impossible to talk of pathological or characteristic heterogeneity

Wechsler and intraindividual variability (dispersion) - ctd

- At the intraindividual level, the difference (5% threshold) between own mean score and a given score (at the intraindividual level) varies between 3.2 (Digit span) and 4.3 (Symbol Digit) depending on task (Manuel WISV IV, Table 51, Grégoire)
- Number of standard scores significantly « deviant »: between 1.1 et 1.4 in the various age groups and depending on IQ (1.0 for IQ 120 and + 1.5 for IQ lower than 80)

Nb notes déviantes	N	%
0	386	35
1	346	31.4
2	229	20.8
3	99	9
4	36	3.3
5	5	0.5
6	2	0.2

Tableau 54, Grégoire 2009

A homogeneous profile (with no significantly deviant score) is the exception (35%) rather than the norm.

Very little work of this kind with cognitive tasks across development
Requires multivariate design
Problem of assessing dispersion with standardized scores across taks => relies also on interindividual differences, even when ipsatized

Intraindividual variability in the brain (inconsistency) – McIntosh et al.

- Children and young adults (EEG): Face processing
- Very young children(EEG)
- Young adults and older adults (BOLD): Fixation task and cognitive activation

Brain becomes more variable with age (children – young adults), and less variable with age (adulthood). Brain variability correlates with behavioral variability (RTs): the most stable at the behavioral level show more variability in the brain

Collectively, the three empirical studies reviewed here demonstrate that brain noise changes with maturation and aging, and suggests that this change correlates with stable behavior. (McIntosh et al., 2010)

Inconsistency in the brain– McIntosh et al. - ctd

Brain mean and overall variability account for age differences

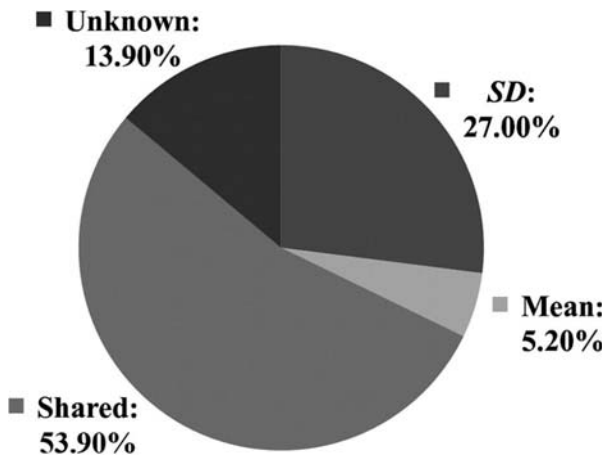


Figure 5. Relative contributions of SD- and mean-based brain measures for predicting chronological age. Values represent unique percentage variance accounted for in chronological age. "Shared" represents predictive overlap between mean- and SD-based measures; "Unknown" represents variance not accounted for by either mean- or SD-based measures. We found no interaction between the effects of mean and SD on age.

Garrett et al. • BOLD Variability Is More than Just Noise J. Neuroscience, 2010, 30(14):4914–4921; p. 4919

Inconsistency in the brain– McIntosh et al. - ctd

- *BOLD variability exhibits a spatially coherent pattern, highly differentiates from the BOLD mean, and robustly relates to age.*
- *Given our results, we find no reason to simply consider BOLD variability as "noise." As Faisal et al. (2008) appropriately state, ". . . to understand the nervous system we have to distinguish variability from noise by accounting for its sources and appreciate the way in which it influences the brain's structure and function" (p. 300).*
- *Variance-based measures may in fact reveal a host of novel brain-related effects not previously considered in fMRI research, while simultaneously bridging to other research areas in which neural variability is expected and even functional (Stein et al., 2005; Faisal et al., 2008; McIntosh et al., 2008). Indeed, it seems that BOLD variability provides a new "signal" that deserves careful consideration.*

Garrett et al. • BOLD Variability Is More than Just Noise J. Neuroscience, 2010, 30(14):4914–4921-

Inconsistency in the brain– McIntosh et al. - ctd

The present results may seem at odds with the intuitive notion of behavior and brain variability, where one would expect that they go hand in hand. However, the results do make sense when the nonlinear dynamics of the nervous system are considered. Internal variability may be vital to enable the brain to parse weak and ambiguous incoming signals (Douglass et al., 1993; Traynelis and Jaramillo, 1998; Destexhe and Contreras, 2006). Variability can facilitate the exchange of signals between neurons (Stacey and Durand, 2000), transitions in metastable systems (McNamara and Wiesenfeld, 1989), and the formation of functional networks (Fuchs et al., 2007) ...

Our modeling work presented in this issue (Jirsa et al.) demonstrates the importance of noise in producing the spatiotemporal dynamics that underlie resting-state in the primate brain.

McIntosh et al. The development of a noisy brain. *Archives Italiennes de Biologie, 148: 323-337, 2010.*

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The Geneva Variability study as an illustration

Nathalie Mella