Developing a Measure of Cognitive Flexibility for Idiographic Data Analyses
Dian Yu, Paul A. Chase, Yerin Park, and Richard M. Lerner, Tufts University

Background
- Traditional developmental research infers individual-level findings from population-based averages (variable-centered).
- Findings from average or aggregated data analysis may not represent individuals, resulting in ineffective policies and interventions (Ramey et al., 2013).
- Ecological Fallacy Principle suggests that development is specific to individuals, times, domains, and contexts; therefore, developmental research should use idiographic (i.e., person-specific) methods to capture individuality before data aggregation.

Research Goals
The Measures and Methods Across the Development Continuum (MMDC) project adapted a short version of the Dimensional Change Card Sort (DCCS) task (Zelazo et al., 2018). This study aims at examining the following two questions:
1. Can the short DCCS capture intra-individual variability across measurement occasions, and are individual trajectories sufficiently represented by trajectories of group-based averages?
2. Are there meaningful intra-individual variabilities on the day- and trial-level?

Participants & Procedure
- 39 participants from Grade 4, 10, 11, and 12 completed 39 or more measurement occasions.
- About three times a week, participants completed the Short DCCS task on a computer in a classroom.

Measures
- Cognitive flexibility was measured via the Short DCCS Task.
- Participants were asked to match the pattern either by color (5 trials) or shape (5 trials) in 10 randomized trials (see illustration below).
- Scores of the DCCS showed evidence of concurrent validity (DCCS scores were correlated with scores for another component of EF, i.e., score on a measure of response inhibition).
- The scores appeared developmentally meaningful (i.e., as expected older participants performed better than younger participants).
- Trials are categorized based on type of color (i.e., matching on color) and shape (i.e., matching on shape) or based on relative order as shifted (e.g., color followed by shape) and non-shifted (e.g., color followed by color).
- Accuracy score (Percentage of correct trials out of total valid trials * 10) and median reaction time were computed.

Results

Research Question 1
- Line graphs (on the right) of daily DCCS accuracy scores (correct trials out of 10) and daily DCCS median reaction times were created using the first 30 measurement occasions for all individuals as well as group-based average.
- Trajectories of accuracy appeared to be stable across 30 measurement occasions, but trajectories of individuals were fluctuating with different patterns across 30 measurement occasions.

Research Question 2
- On the day-level, bivariate correlations between sleep and mood and DCCS performance were conducted for each individual.
- Quality of sleep and mood contributed to some participants’ performance variability.
- E.g., for participant #24, better mood and sleep was correlated with higher accuracy, but not correlated with reaction time.
- E.g., for participant #25, better mood and sleep was correlated with faster reaction time, but not accuracy.
- On the trial level, independent t-tests were conducted for all trials across all measurement occasions based on trial type or relative order for each participant, respectively (see illustrations on the right).

Discussion and Conclusions
- The Short DCCS task appeared to be change-sensitive and captured intra-individual variability across time.
- Individual trajectories cannot be represented by trajectories of group-based average.
- Individual variance across time is not errors that we should get rid of by creating group-based averages; instead, individual variance across time provides meaningful information.
- Specific factors (e.g., mood and sleep) can contribute to daily individual variability, and how such factors contribute to individual variability may vary from person to person.
- Developing change-sensitive tools and using idiographic approaches are necessary for developmental science, as they allow researchers to disaggregate data and draw conclusions based on individuals specifically instead of informing group-based information.

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Background
- Traditional developmental research infers individual-level findings from population-based averages (variable-centered).
- Findings from average or aggregated data analysis may not represent individuals, resulting in ineffective policies and interventions (Rose et al., 2013).
- Bornstein’s (2017) Specificity Principle suggests that development is specific to individuals, times, domains, and contexts; therefore, developmental research should use idiographic (i.e., person-specific) methods to capture individuality before data aggregation.

- To move toward an idiographic approach, we must adopt measures that are sensitive to intra-individual change.
- Cognitive flexibility is the ability to shift the focus of attention flexibly according to different demands, and it is associated with key youth adjustments (Garon et al., 2008).
- Studying cognitive flexibility idiographically requires a change-sensitive measurement tool. However, none of the existing measures have been used with intensive longitudinal measures.

Research Goals
The Measures and Methods Across the Development Continuum (MMDC) project adapted a short version of the Dimensional Change Card Sort (DCCS) task (Zelazo et al., 2013). This study aims at examining the following two questions:

1. Can the short DCCS capture intra-individual variability across measurement occasions, and are individual trajectories sufficiently represented by trajectories of group-based averages?
2. Are there meaningful intra-individual variabilities on the day- and trial-level?
Participants & Procedure

- 39 participants from Grade 4, 10, 11, and 12 completed 30 or more measurement occasions ($M = 34$, $SD = 2.99$)
- About three times a week, participants completed the Short DCCS task on a computer in a classroom

![Participants Pie Chart]

Measures

- Cognitive flexibility was measured via the Short DCCS Task
- The participants were asked to match the pattern either by color (5 trials) or shape (5 trials) in 10 randomized trials (see illustration below).
- Scores of the DCCS showed evidence of concurrent validity (DCCS scores were correlated with scores for another component of EF, i.e., score on a measure of response inhibition).
- The scores appeared developmentally meaningful (i.e., as expected older participants performed better than younger participants).
- Trials are categorized based on type as color (i.e., matching on color) and shape (i.e., matching on shape) or based on relative order as shifted (e.g., color followed by shape) and non-shifted (e.g., color followed by color).
- **Accuracy score** (Percentage of correct trials out of total valid trials * 10) and **median reaction time** were computed.
• **Sleep and mood** were measured via single Likert items
• Participants select the item that best describes how they feel at the moment (see illustration on the right)

How well did you sleep last night?

I slept...
- Terribly
- Poorly
- OK
- Well
- Very Well

How is your mood right now?

My mood is...
- Terrible
- Poor
- So-so
- Good
- Great

**Results**

Research Question 1

- Line graphs (on the right) of **daily DCCS accuracy scores** (correct trials out of 10) and **daily DCCS median reaction times** were created using the first 30 measurement occasions for all individuals as well as group-based average

- Trajectories of averages appeared to be stable across 30 measurement occasions, but trajectories of individuals were fluctuating with different patterns across 30 measurement occasions!
Research Question 2

- **On the day-level**, bivariate correlations between sleep and mood and DCCS performance were conducted for each individual

- Quality of sleep and mood contributed to some participants’ performance variability
  - E.g., for participant #24, better mood and sleep was correlated with higher accuracy, but not correlated with reaction time
  - E.g., for participant #28, better mood and sleep was correlated with faster reaction time but not accuracy
On the trial-level, independent $t$-tests were conducted for all trials across all measurement occasions based on trial type or relative order for each participant, respectively (see illustrations on the right).

- About half of the participants responded significantly faster to color trials than shape trials (e.g., ID 22)
- The rest did not respond differently (e.g., ID 25)
- Most participants did not demonstrate different accuracy for color and shape trials (e.g., ID 23)
- Some participants showed higher accuracy for color than shape trials (e.g., ID 26)
- Some participants showed higher accuracy for shape than color trials (e.g., ID 355)
• The order of trials did not impact the reaction time for most participants (e.g., ID 67)
• Two participants responded significantly faster to non-shifted than shifted trials (e.g., ID 468).

![DCCS Reaction Time by Order](chart)

![DCCS Accuracy by Order](chart)

• The order of trials did not impact the accuracy for the majority of participants (e.g., ID 351)
• Several participants had higher accuracy for non-shifted than shifted trials (e.g., ID 30).
Discussion and Conclusions

- The Short DCCS task appeared to be change-sensitive and captured intra-individual variability across time.
- Individual trajectories cannot be represented by trajectories of group-based averages.
- Individual variance across time are not errors that we should get rid of by creating group-based averages; instead, individual variance across time provides meaningful information.
- Specific factors (e.g., mood and sleep) can contribute to daily individual variability, and how such factors contribute to individual variability may vary from person to person.
- Developing change-sensitive tools and using idiographic approaches are necessary for developmental science, as they allow researchers to disaggregate data and draw conclusions based on individuals specifically instead of inferring group-based information.
References