Time is on my side: What British rock bands can teach us about designing longitudinal studies

Matt Fritz **MAP Academy**
Educational Psychology
University of Nebraska – Lincoln

Track Listing

1. **Long Away** – *Queen*
2. **Changes** – *David Bowie*
3. **Should I Stay or Should I Go** – *The Clash*
4. **Half a Person** – *The Smiths*
5. **Acquiesce** – *Oasis*
6. **Low Budget** – *The Kinks*
7. **You Can't Always Get What You Want** – *The Rolling Stones*
8. **Looking for Somebody** – *Fleetwood Mac*
9. **I Don't Even Know Myself** – *The Who*
10. **That's the Way** – *Led Zeppelin*
11. **Too Much Information** – *The Police*

Track 01

Long Away – *Queen*

A Day at the Races (1976)

"Did we leave our way behind us
Such a long long way behind us
Who knows when, now who knows where
Where the light of day will find us?"

Written by: Brian May

Longitude

- The word **longitudinal** comes from the term **longitude**, which is the distance east or west of a north-south meridian.

- "*The measurement of longitude meridians… is tempered by time. To learn one's longitude at sea, one needs to know what time it is aboard ship and also the time at the home port or another place of known longitude – at that very same moment. The two clock times enable the navigator to convert the hour difference into a geographical separation…*

  [E]ach hour's time difference between the ship and the starting point marks a progress of fifteen degrees of longitude east or west. Every day at sea, when the navigator resets his ship's clock to local noon when the sun reaches its highest point in the sky, and then consults the home-port clock, every hour's discrepancy between them translates into another fifteen degrees of longitude."
  (Sobel, 1995, pp 4-5)

Time is Relative

- **Time** is a necessary component of longitudinal data.

- Note, however, that Sobel (1995) says that longitude is measured from a "*home port or another place of known longitude*".

- This implies that there is not one specific correct origin time or measurement occasion to which every other measurement must be compared.

- Instead, where we decide to start counting time from (i.e., where *time* = 0) will depend on our data, hypotheses, study design, and model.

- Why do we care about time?

Track 02

Changes – *David Bowie*

Hunky Dory (1971)

"Strange fascination, fascinating me
Changes are taking the pace I'm going through

Ch-ch-ch-changes (turn and face the strange)
Ch-ch-ch-changes"

Written by: David Bowie

Intra vs. Inter

- Because we are interested in change!!!
- Differences or variability that exist between individuals or cases are called **inter-individual differences**.
- Changes or variability that exists within an individual or case are called **intra-individual change**.
- **Cross-sectional data**, data measured at a single point in time, can only measure inter-individual change, not intra-individual change.
- Hence, if you want to measure change, you MUST have **longitudinal data** which are measured at multiple points in time.

Temporal Precedence

- Also, time is a very important factor in causal modeling because of the issue of temporal precedence.

- **Temporal precedence** states that in order for an effect to occur, time must elapse, such that causes must proceed effects in time (Holland, 1986).

- This means that causal models, including mediation, should not be estimated on cross-sectional data (Cole & Maxwell, 2003; Maxwell & Cole, 2007)!

- The question then becomes:
  how much time must elapse for an effect to occur?

- A related question that must be considered is:
  what if the magnitude of the effect changes over time?

Track 03

Should I Stay or Should I Go

– *The Clash*

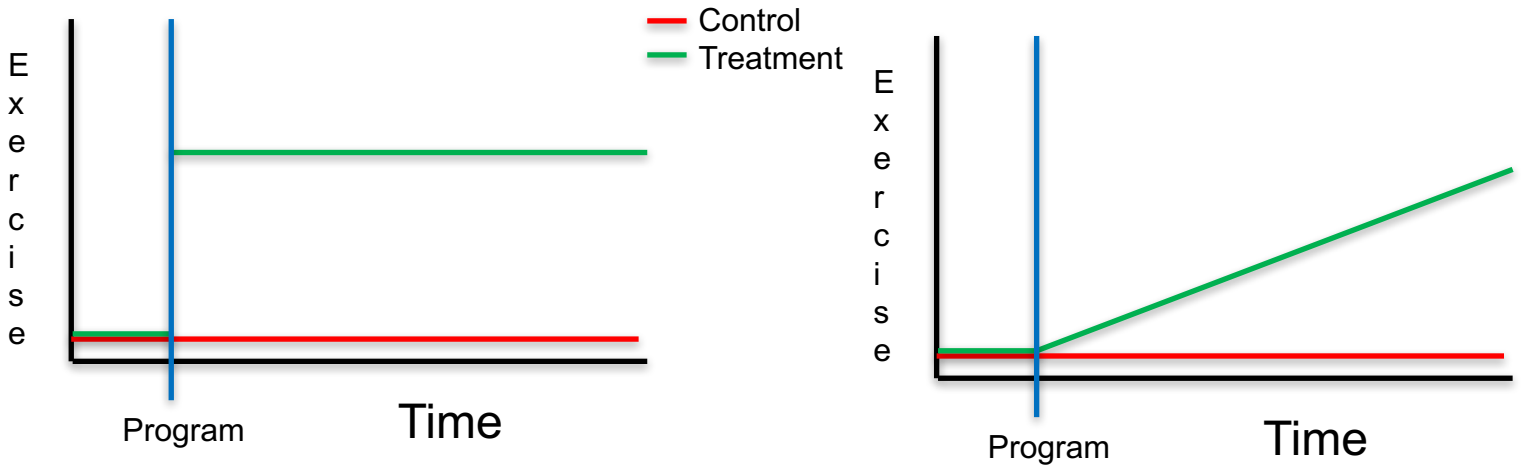
Combat Rock (1982)

"One day it's fine and next it's black"

Written by: Topper Headon, Mick Jones, Paul Simonon, & Joe Strummer

Extinguishing and Delayed Effects 1

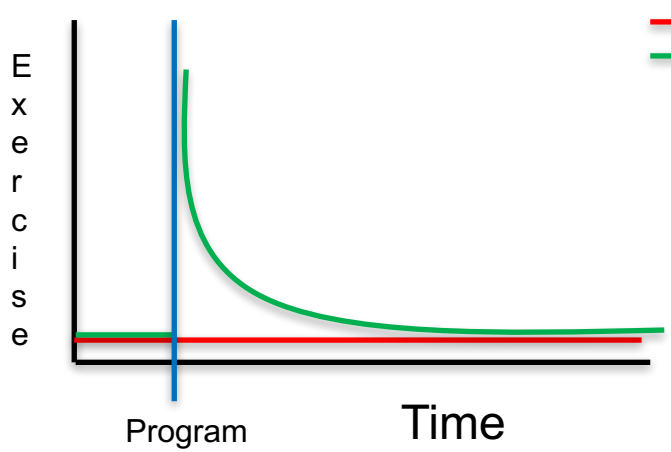
- Considering the shape of change is particularly important because not all change occurs consistently or begins immediately.
- Consider a treatment program to increase exercise in adults.
- One possibility is a **uniform effect** **(left)**.

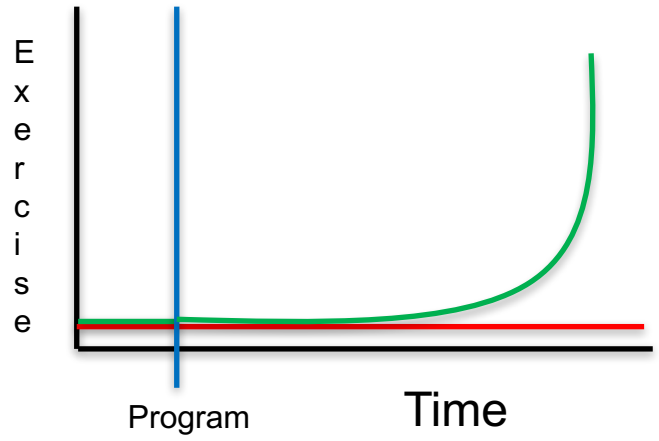


- Another option is a **linear effect** (right).

Extinguishing and Delayed Effects 2

- Another possibility is an **extinguishing** or **decaying effect** (left).





- Another is a **delayed effect** (right).
- Which of these effects do we actually predict in our hypotheses?
- Maybe more importantly, what do we mean by "effect"?
- Why do we care?

Track 04

Half a Person – *The Smiths*

The World Won't Listen (1987)

"I've spent six years on your trail
Six full years of my life on your trail
And if you have five seconds to spare
Then I'll tell you the story of my life"

Written by: Johnny Marr & Morrissey

Temporal Design 1

- Hence, we need to consider not only the total elapsed time between our first and last measurement, but also the total number of measurements being made (also called the number of **waves**) as well as the spacing of the measurements.

- These three factors together make up the **temporal design** of a study (Collins, 2006; Collins & Graham, 2002).

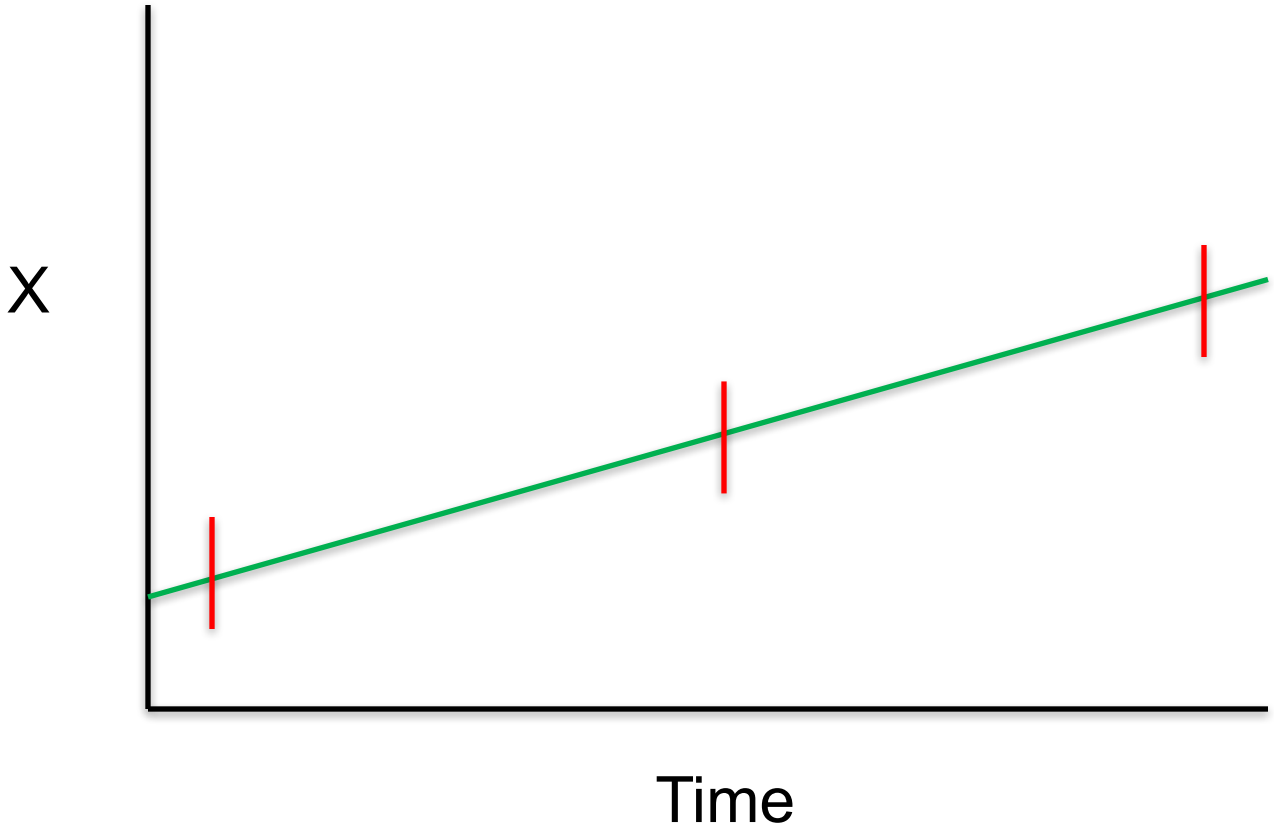
- The temporal design is one of the most important issues to consider when conducting a longitudinal study because if we get the temporal design wrong we may underestimate or completely miss an effect.

- We may also model the shape of the change across time for a variable (i.e., the **trajectory**) incorrectly.

- Two years of data!!!

Temporal Design 2

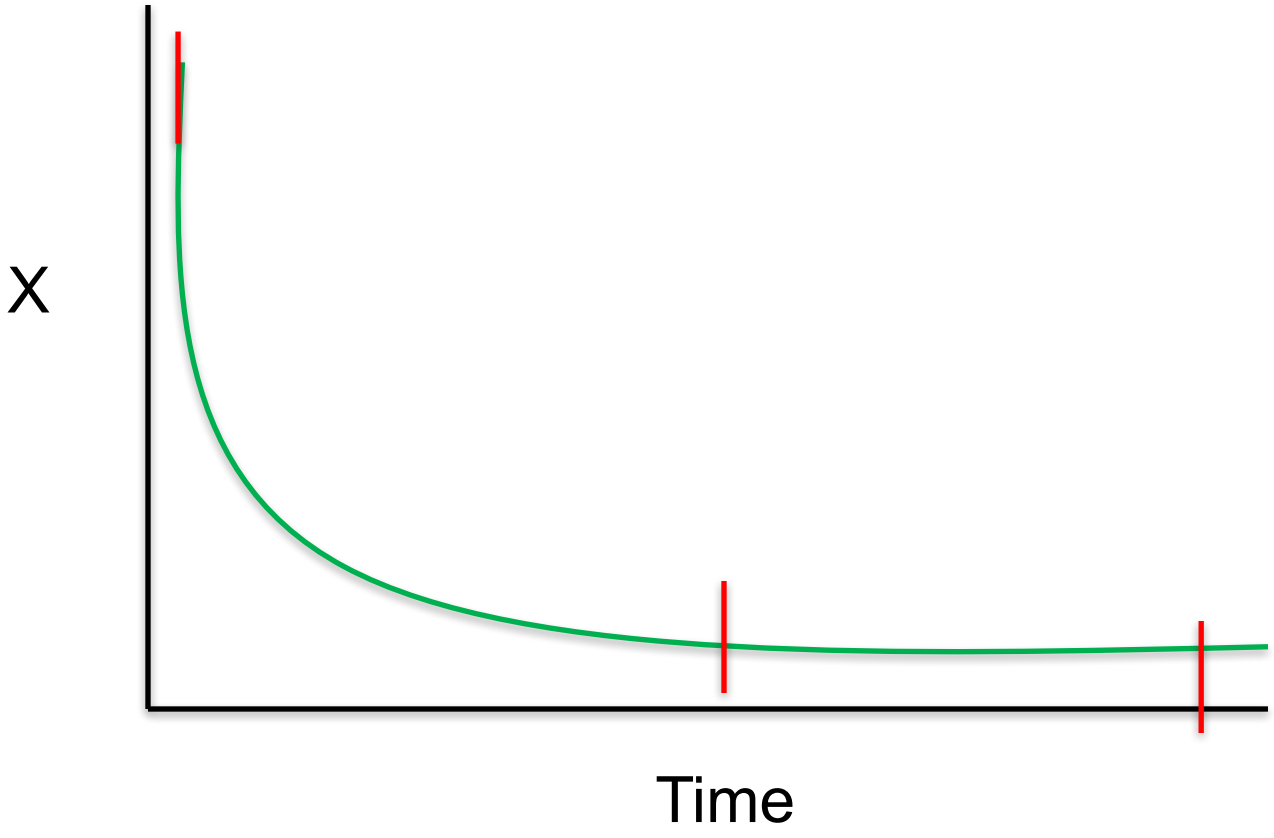
- Is this a good temporal design?



Three equally spaced measurements.

Temporal Design 3

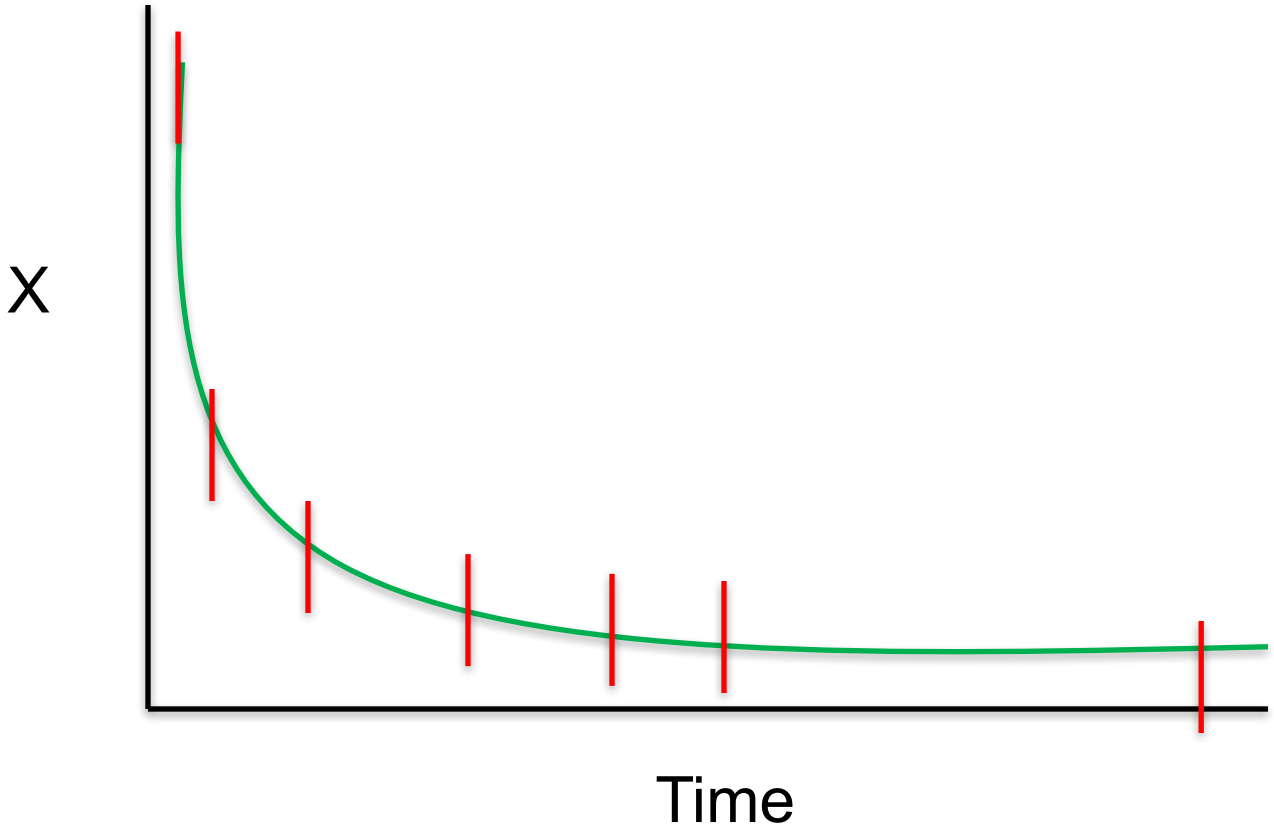
- Is this a good temporal design?



Three equally spaced measurements.

Temporal Design 4

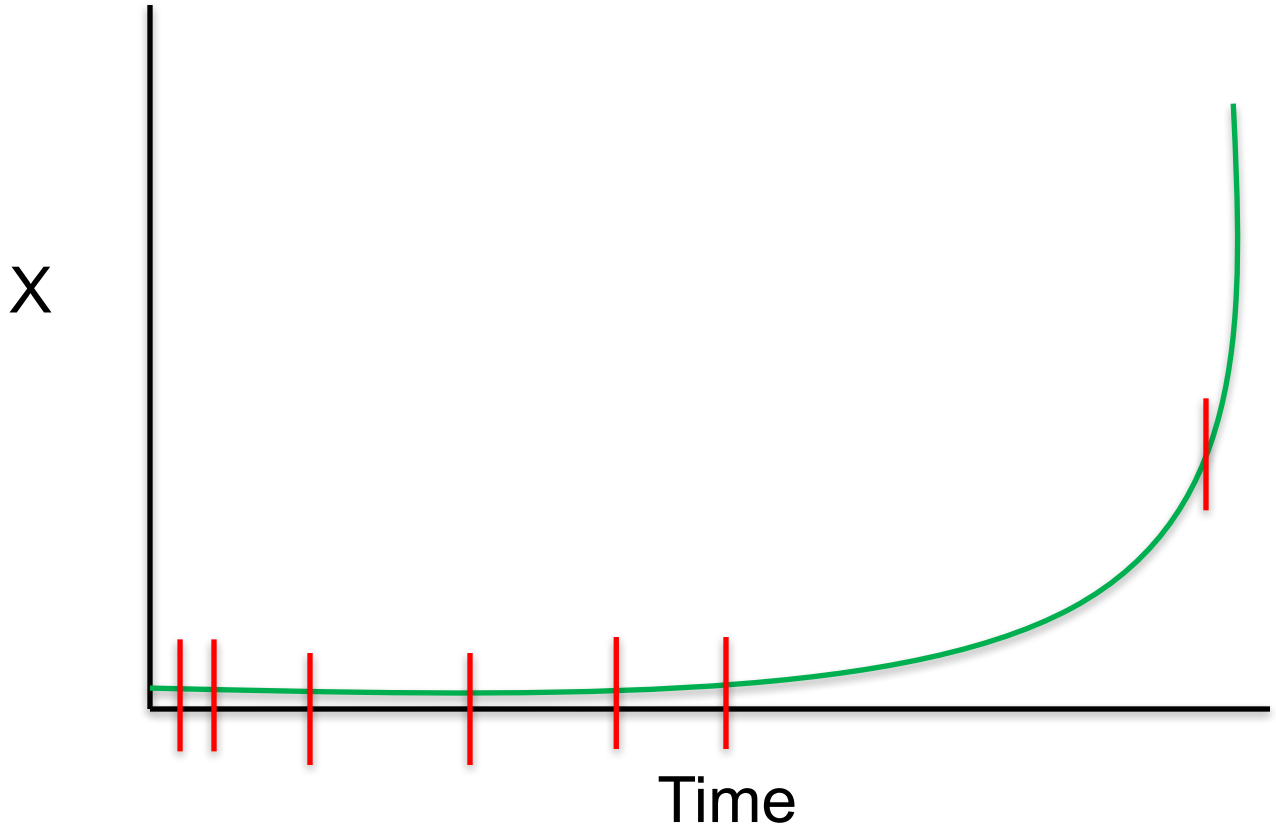
- Is this a good temporal design?



Six equally spaced measurements in the first half of the total elapsed time and one measurement at the end of the elapsed time.

Temporal Design 5

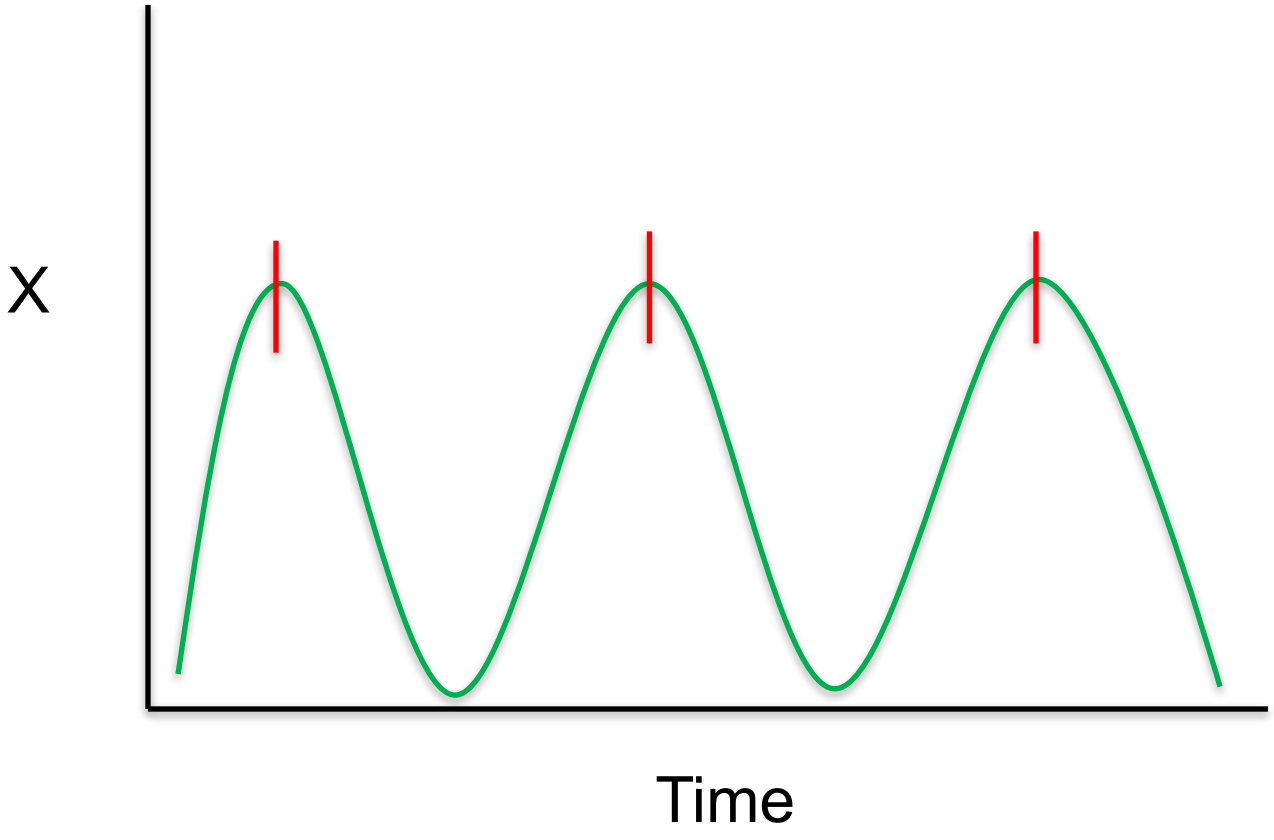
- Is this a good temporal design?



Six equally spaced measurements in the first half of the total elapsed time and one measurement at the end of the elapsed time.

Temporal Design 6

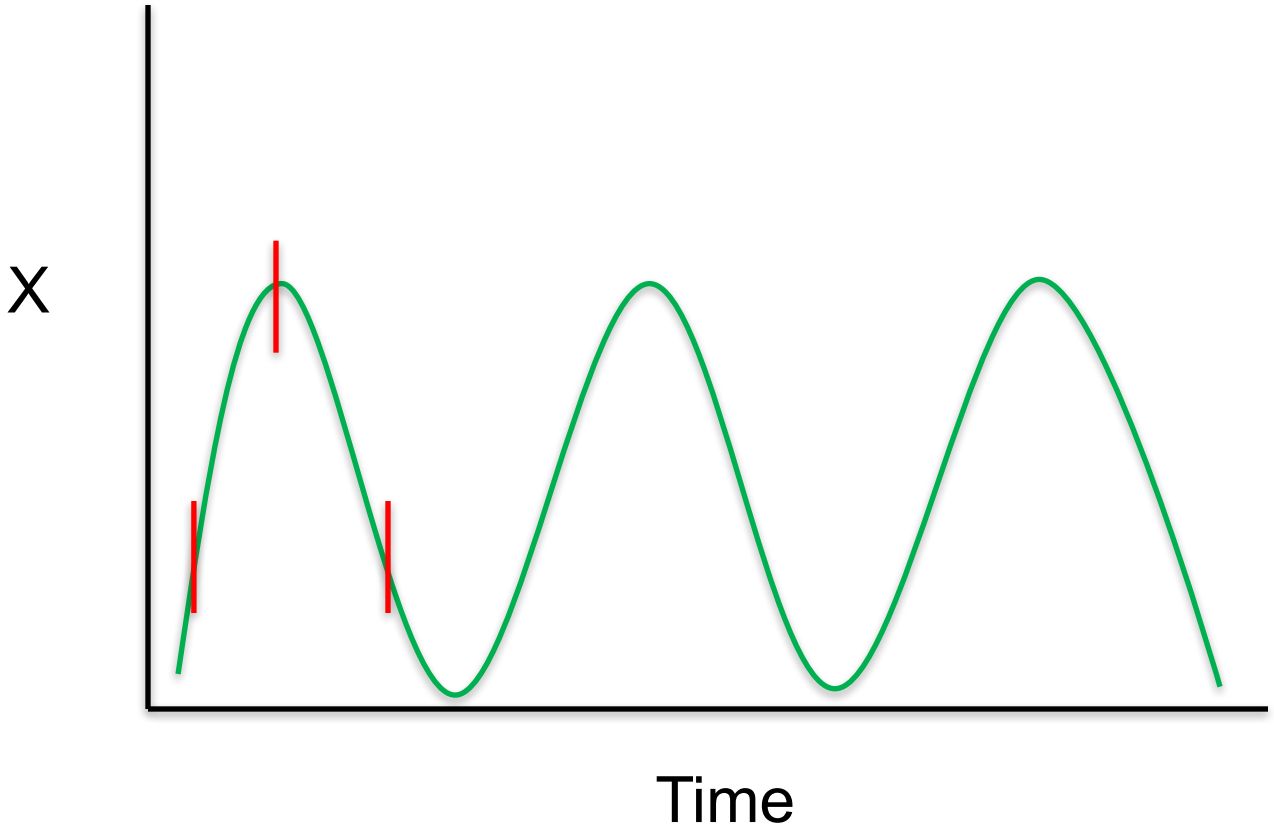
- Is this a good temporal design?



Three equally spaced measurements.

Temporal Design 7

- Is this a good temporal design?



Three equally spaced measurements.

Temporal Design 8

- But what if we do not know the exact shape or elapsed time needed for the effect?
- I know - more measurements!
- The more measurements you have, the more likely you are to capture the underlying effect - maybe.
- More measurements does not guarantee you will capture the effect, however, and can actually increase the amount of bias in your model (Kelley & Maxwell, 2008).
- It may also limit the available sample size.
- But aren't all longitudinal data the same?

Track 05

Acquiesce – *Oasis*
The Masterplan (1998)

"There are many things that I would like to know
And there are many places that I wish to go
But everything's depending on the way the wind may
blow"

Written by: Noel Gallagher

Panels, ILD, and Time Series 1

- Longitudinal data can be broken down into three broad, loosely defined categories based on the total number of repeated measurements and sample size.

1. **Panel data** (Kessler & Greenberg, 1981) tend to consist of a smaller number of repeated measurements (e.g., < 10) usually collected on a **panel** that consists of a large number of individuals (e.g., $n > 400$).

   – For example, standardized math scores for high schoolers in Nebraska measured once a year for five years.

2. **Intensive longitudinal data (ILD)** (Bolger & Laurenceau, 2013; Wall & Schafer, 2006) usually consist of a medium number of repeated measures measurements (e.g., < 50) usually collected on a smaller number of individuals (e.g., $n = 40$).

   – For example, alcohol use measured daily for 30 days for students in a statistics class.

Panels, ILD, and Time Series 2

- ILD can include **diary studies** and **ecological momentary assessment (EMA)** data (Mehl & Conner, 2012; Stone, Shiffman, Atienza, & Nebeling, 2007).

3. **Time series data** are longitudinal data with a very large number of repeated observations (e.g., > 50) on a single unit (Greene, 2000).

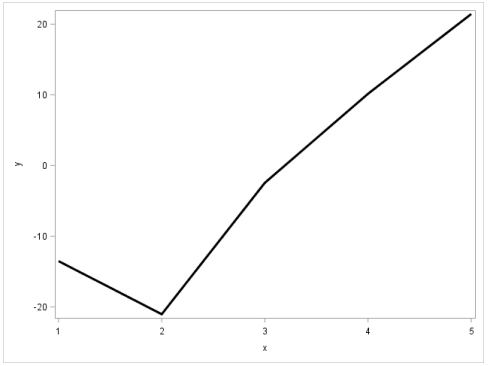
   - For example, the number of inches of rain in Lincoln, NE measured daily for the past 10 years.

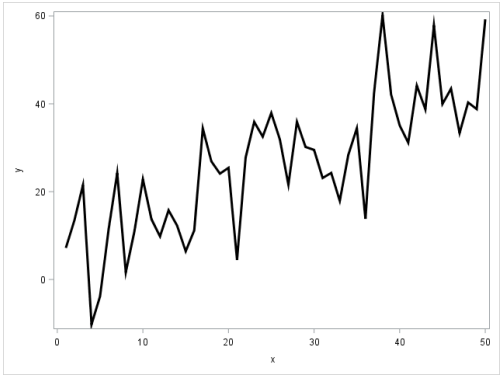
- Note - these are very loosely defined terms, however, and often overlap or are used interchangeably.

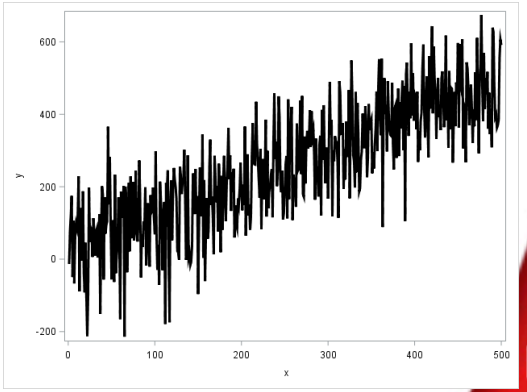
- Why do we care?

One Model Does Not Fit All

- No “one-size-fits-all” longitudinal model.
- Just because you have longitudinal data does not mean you should always fit a growth curve model.
- In general, different statistical techniques and strategies are used for data from these different types of longitudinal data.
- Noise filter.







- We also care because we are on a:

Track 06

Low Budget – *The Kinks*

Low Budget (1979)

"Circumstance has forced my hand
To be a cut price person in a low budget land
Times are hard but we'll all survive
I just got to learn to economize
I'm on a low budget"

Written by: Ray Davies

Planned Missingness 1

- Suppose we are interested in the relation between screen time and obesity in children.
- In general, we can collect more data (larger sample size and/or more waves of data) with less expensive measures - e.g., measure body fat with BMI.
- Or we can collect less data (smaller sample size and/or fewer waves of data) with more expensive measures – e.g., measure body fat with dual-energy X-ray absorptiometry (DEXA).
- But why do we have to collect all the same measures on everyone?
- To avoid missing data, which biases our estimates, right?
- Missing data are only a problem when we do not know why they are missing.

Planned Missingness 2

- If we randomly assign some children to take the expensive measure and all children to take the inexpensive measure, then the data on the children who did not take the expensive measure are **missing completely at random (MCAR)**.
- And MCAR data do not bias results.
- Also, it allows us to examine the accuracy of the inexpensive measure.
- This is called **missing by design** or **planned missingness**.
- We could also randomize which questions/scales from a long questionnaire specific individuals received at a time point.
- Or randomize individuals to not be measured at all at specific waves.
- But won't that affect our power?

Track 07

You Can't Always Get What You Want – *The Rolling Stones*

Let It Bleed (1969)

"You can't always get what you want
But if you try sometimes
You just might find,
You get what you need
Oh yeah!"

Written by: Keith Richards & Mick Jagger

Doing More With Less

- Yes, but depending on the design, possibly not by much.

- Graham, Taylor, and Cumsille (2001) considered a study with 1000 participants and 5 waves of data:

			Wave						
	1	2	3	4	5	n		Measurements	Power
Complete	X	X	X	X	X	1000		5000 (100%)	0.822
Missing 1	X	X	X	X	X	167		4164 (83.33%)	0.773
	X	X	X	X	0	167			
	X	X	X	0	X	167			
	X	X	0	X	X	167			
	X	0	X	X	X	166			
	0	X	X	X	X	166			
Missing 3C	X	X	X	X	X	91		3282 (63.64%)	0.747
	X	X	X	0	0	101			
	X	X	0	X	0	101			
	X	0	X	X	0	101			
	0	X	X	X	0	0			
	X	X	0	0	X	202			
	X	0	X	0	X	202			
	0	X	X	0	X	0			
	X	0	0	X	X	202			
	0	X	0	X	X	0			
	0	0	X	X	X	0			

Track 08

Looking for Somebody

– *Fleetwood Mac**

Peter Green's Fleetwood Mac (1968)

"Yeah, I got a feeling, blues going to be my only way
But when you're looking for somebody
I'm looking for somebody"

Written by: Peter Green

*Original line-up: Peter Green, Mick Fleetwood, John McVie, and Jeremy Spencer

Unplanned Missingness

- Missing data in longitudinal studies are almost unavoidable.
- Unfortunately, many of us have gotten overly reliant on modern statistical methods for missing data (e.g., MI and FIML).
- The best way to deal with missing data is to not have missing data.
- Have a plan to get try to minimize missing data – incentives (e.g., a bonus for completing all measurements), extra follow up procedures for no shows (i.e., beyond email), multiple points of contact (for lost cases), and alternative measurement scenarios (measures that can be administered at a person's home instead of the schools/lab).
- Another strategy is to randomly select a sample of the people who have attrited from your study and try to track them down in order to determine exactly why they left the study – this is much more informative than comparing baseline demographics for the missing and complete cases.

Track 09

I Don’t Even Know Myself

– The Who

Who’s Next (1971)

“There's nothing in the way I walk
that could tell you where I'm going
There's nothing in the words I speak
that can betray anything I'm knowing
Don't think about the way I dress,
you can fit me on a labeled shelf
Don't pretend that you know me
cause I don't even know myself”

Written by: Pete Townshend

Linked Data

- In order to test models of change, there must be a way to link the data from the repeated measurements to a specific case.
- But that can cause problems with IRB – Tale of Brave Ulysses.
- An alternative is **self-generated identification codes** (e.g., Yurek, Vasey, & Sullivan, 2008).
- Needs to be long enough so the code is unique and needs to be based on easily remembered facts that do not change.
- For example:
  - First letter of mother's maiden name
  - Last digit of birth year
  - Last letter of first name
  - First letter of birth town

Track 10

That's the Way – *Led Zeppelin*

Led Zeppelin III (1970)

"I don't know what to say about it
When all you ears have turned away
But now's the time to look and look again at what you see
Is that the way it ought to stay?"

Written by: Robert Plant & Jimmy Page

Should I Change It?

- What if you are conducting an intervention and after the first post-treatment measurement, it is working for some people, but not others.
- Should you continue the intervention for everyone?
- One way to deal with this is by using a **Sequential Multiple Assignment Randomized Trial (SMART**; Lei et al., 2012).
- A series of decision criteria are defined before the intervention and then at each wave, individuals who are not responding to treatment are randomized to alternative treatments.
- For example, a subgroup of people not responding to a CBT might then be randomized to keep getting the CBT or get the CBT and drugs.
- OK – I know what you're thinking…

Track 11

Too Much Information

– *The Police*

Ghost in the Machine (1981)

"Too much information running through my brain
Too much information driving me insane"

Written by: Sting

But…

Hidden Bonus Track

Getting Better – *The Beatles*

Sgt. Peppers Lonely Hearts Club Band (1967)

"I've got to admit it's getting better (Better)
It's a little better all the time (It can't get no worse)"

Written by: John Lennon & Paul McCartney

Recommended Artists

- Collins, L. M., & Horn, J. L. (Eds.). (1991). *Best methods for the analysis of change.* Washington, D.C.: American Psychological Association.

- Collins, L. M., & Sayer, A. G. (Eds.). (2001). *New methods for the analysis of change.* Washington, D.C.: American Psychological Association.

- Laursen, B., Little, T. D., & Card, N. A. (Eds.). (2012). *Handbook of developmental research methods.* New York: Guilford.

- Mehl, M. R., & Conner, T. S. (Eds.). (2012). *Handbook of research methods for studying daily life.* New York: Guilford.

- Bolger, N., & Laurenceau, J.-P. (2013). *Intensive longitudinal methods: An introduction to diary and experience sampling research.* New York: Guilford.

Liner Notes

Bolger, N., & Laurenceau, J.-P. (2013). *Intensive longitudinal methods: An introduction to diary and experience sampling research*. New York: Guilford.

Cole, D. A., & Maxwell, S. E. (2003). Testing mediational models with longitudinal data: Questions and tips in the use of structural equation modeling. *Journal of Abnormal Psychology, 112, 558-577.*

Collins, L. M. (2006). Analysis of longitudinal data: The integration of theoretical model, temporal design, and statistical model. *Annual Review of Psychology, 57*, 505-528.

Collins, L. M., & Graham, J. W. (2002). The effect of the timing and spacing of observations in longitudinal studies of tobacco and other drug use: Temporal design considerations. *Drug and Alcohol Dependence, 68*, S85-S96.

Graham, J. W., Taylor, B. J., & Cumsille, P. E. (2001). Planned missing data designs in the analysis of change. In L. M. Collins & A. G. Sayer (Eds.), *New methods for the analysis of change* (pp. 335-353). Washington, D.C.: APA.

Greene, W. H. (2000). *Econometric analysis* (4th ed.). Upper Saddle River, NJ: Prentice Hall.

Holland, P. W. (1986). Statistics and causal inference. *Journal of the American Statistical Association, 81*, 945-960.

Kelly, K., & Maxwell, S. E. (2008). Delineating the average rate of change in longitudinal models. *Journal of Educational and Behavioral Statistics, 33*, 307-332. doi: 10.3102/1076998607306074

Kessler, R. C., & Greenberg, D. F. (1981). *Linear panel analysis: Models of quantitative change*. New York: Academic Press.

Lei, H., Nahum-Shani, I., Lynch, K., Oslin, D., & Murphy, S. A. (2012). A "SMART" design for building individualized treatment sequences. *Annual Review of Clinical Psychology, 8*, 14.1-14.28.

Maxwell, S. E., & Cole, D. A. (2007). Bias in cross-sectional analyses of longitudinal mediation. *Psychological Methods, 12, 23-44.*

Mehl, M. R., & Conner, T. S. (Eds.). (2012). *Handbook of research methods for studying daily life*. New York: Guilford.

Stone, A. A., Shiffman, S., Atienza, A. A., & Nebeling, L. (Eds.). (2007). *The science of real-time data capture: Self-reports in health research.* Oxford, UK: Oxford University Press.

Sobel, D. (1995). *Longitude.* New York: Walker and Company.

Walls, T. A., & Schafer, J. L. (Eds.). (2006). *Models for intensive longitudinal data.* Oxford: Oxford University Press.

Yurek, L. A., Vasey, J., & Sullivan Havens, D. (2008). The use of self-generated identification codes in longitudinal research. *Evaluation Review, 32,* 435-452.