Distraction is differentially affected by the driver's gender and digit ratio (2D:4D)

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Starting point…

- Women make more driving errors when talking on the mobile phone than do men.
- This difference is most pronounced when the conversation is emotional in content.

  Irwin, J.D., Geaghan, L. & Chekaluk, E. (2011). Gender effects in mobile phone distraction from driving. In: D. Hennessy, (Ed.), *Traffic Psychology: An International Perspective*, (pp. 115-130). New York: Nova Science Publishers

- **Is the gender difference due to psychosocial or biological factors?**

Originally we claimed that the gender difference is due to psychosocial factors, that the female drivers were more socially engaged with the person to whom they were talking to. The female drivers were more likely to recall the name of the person to whom they were speaking to, and aspects of the conversation, whereas the male drivers were better able to recall aspects of the drive.

But it has been known for at least 40 years in the animal learning and memory literature that **attentional processes** are directly modulated by hormones such as testosterone in a variety of vertebrates**.**

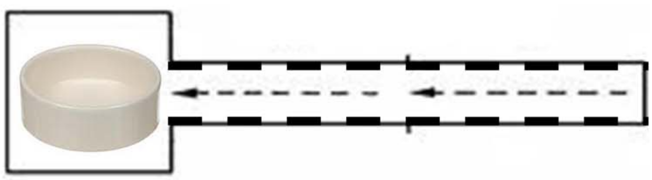
For example, the administration of testosterone to young chicks increases their attention to the primary task of searching for food, and reduces their distraction by the presentation of irrelevant stimuli into the situation.

So the question we wondered was: could it be the **testosterone** in our male drivers that made them less prone to distraction from a concurrent conversation?

Testosterone: Possible biological factor?

The effects of testosterone on chicken behaviour:

- Elevating testosterone levels in chicks increased:
  - their ***search persistence*** for food and, during their search for food,
  - It helped them to ***focus visual attention*** while ***decreasing distraction*** by ***irrelevant stimuli***.
- **This has been demonstrated in a number of different learning tasks.**
  - Change food bowl on test day or change the colours and/or patterns of the sides of the runway.



N.B. the changes did not distract the testosterone treated chicks!

In operant tasks chicks that have not been injected with testosterone **are distracted by changes in irrelevant cues** (i.e. cues that not rewarded), **whereas testosterone-treated chicks were not.** (Andrew and Rogers, 1972; Archer, 1974).
Elevated testosterone levels have also been found to increase an animal's search persistence and, during the search for food, to **focus visual attention while decreasing distraction by irrelevant stimuli**. E.g. only peck red pellets ignore blue ones.

Reduced response to change in irrelevant cues has been demonstrated in a number of tasks.

- **“Reduced distractibility by stimuli irrelevant to the task in hand is the most widely described change in attention due to testosterone** (**man**: Klaiber et al., 1972; **mouse**, Archer, 1977; **rat**, Thomson & Wright, 1979)**.”** Klein and Andrew, (1986), p. 139.

Archer, J. (1977). Testosterone and persistence in mice, *Animal Behaviour, 25,* 479-488.
Klaiber, E.L., Broverman, D.M., Vogel, W., Abraham, G.E. & Cone, F.L. (1972). Effects of infused testosterone on mental performance and ICSH. *The Journal of Clinical Endocrinology & Metabolism, 32*, 341-349.
Distraction, Decisions and Persistence in Runway Tests Using the Domestic Chick
Klein, R. M. & Andrew, R. J. (1986). Distraction, Decisions and Persistence in Runway Tests Using the Domestic Chick, *Behaviour, 99,* 139-156
Thompson, W. R. &Wright, J. S. (1979). "Persistence" in rats: effects of testosterone. *Physiological Psychology, 7*, 291-294.

Testosterone effects in humans

- High testosterone levels can **increase vigilance** and **visuo-motor skills** such as **scanning** and **speed of reactions** in humans – qualities known to be helpful to traders to spot and trade price discrepancies before others arbitrage them away.
- Traders are noted for being testosterone 'fueled'
- Coates et al. (2009) noted that traders with longer ring fingers made 6 times the profits of traders with shorter ring fingers!

Coates, J. M., Gurnell, M. & Rustichini, A. (2009). **Second-to-fourth-digit ratio predicts success among high-frequency financial traders**. *Proceedings of the National Academy of Sciences of the United States of America, 106,* 623–628. (doi:10.1073/pnas.0810907106)

Because individual responses to testosterone can be affected by how much of the hormone you were exposed to in the uterus, Coates wondered if this could also be exerting an effect. So he recruited 49 male traders from the City of London and looked at their index-to-ring-finger ratio - a marker of prenatal testosterone exposure.

Profitable digits

He found that traders with a longer ring fingers, and therefore higher prenatal testosterone, made on average six times the profits of traders exposed to low levels of the hormone, and tended to remain traders for longer.

Previous studies have also suggested a link between a low index-to-ring-finger ratio and autism, and better sporting ability.

Andrew, R. (1991) The development and integration of behaviour. Essays in honour of Robert Hinde (ed. P. Bateson), pp. 171–190. Cambridge, UK: Cambridge University Press.
Andrew, R. & Rogers, L. (1972) Testosterone, search behaviour and persistence. Nature 237, 343–346. (doi:10. 1038/237343a0)
Coates, J. M., Gurnell, M. & Rustichini, A. (2009) Second-to-fourth-digit ratio predicts success among high-frequency financial traders. Proc. Natl Acad. Sci. USA 106, 623–628. (doi:10.1073/pnas.0810907106)

Testosterone effects in humans

- Digit ratio (2D:4D) is associated with traffic violations for male frequent car drivers (Schwerdtfeger, Heims & Heer, 2010)

'I'm not writing him out a ticket ... you do it!"

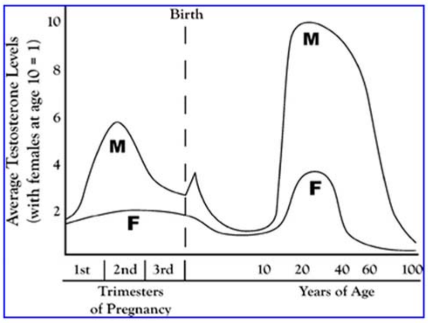
Schwerdtfeger, Heims & Heer, (2010). Digit ratio (2D:4D) is associated with traffic violations for male frequent car drivers, *Accident analysis and prevention, 42,* 269-274.

Digit ratio was inversely related to the acquisition of penalty points (accrued over a 5-year period), suggesting more traffic violations for individuals with higher prenatal testosterone exposure.

Traffic offense behaviour was assessed via self-reported penalty points as registered by the Central Register of Traffic Offenders in Germany. Results showed that digit ratio was inversely related to penalty point entries, suggesting more traffic violations for individuals with higher prenatal testosterone exposure.
Sensation seeking was positively associated with traffic violations, but there was no relationship between sensation seeking and digit ratio, proposing additive effects of both variables.

The results suggest that prenatal androgen exposure might be related to traffic violations for frequent car drivers.

Digit ratio (2D:4D) is a putative marker for the sensitivity to and/or amount of **prenatal testosterone** experienced by the foetus at weeks 8-12



The life-cycle average **testosterone** levels for males (M) and females (F)

Figure from: Ellis, L. (2011). Identifying and explaining apparent universal sex differences in cognition and behavior, *Personality and Individual Differences, 51*, 552-561.

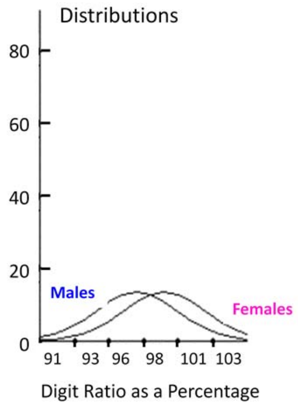
Ellis, L. (2004). Sex, status, and criminality: A theoretical nexus. *Social Biology, 51*, 144–160.

It has been known for over a century that the 2D:4D ratio is a sexually differentiated characteristic (Baker, 1888). The ratio of the length of the index finger to that of the ring finger (the 2D:4D ratio) is a widely studied and accepted marker for masculinisation through **prenatal androgen exposure**, in particular testosterone in such a way that higher testosterone relative to oestrogen exposure is associated with a lower 2D:4D ratio (Hönekopp, Bartholdt, Beier & Liebert, 2007; Manning et al., 2010; Manning & Taylor, 2001; Voracek, Pum & Dressler, 2010).)

It has been found that this ratio does not change at puberty and is **most likely fixed prenatally, at the end of the first trimester** (Garn, Burdi, Babler & Stinson, 1975; Manning et al., 1998).

Most importantly for research into the effects of testosterone over the lifespan, **the 2D:4D ratio is negatively associated with postnatal testosterone levels in men** (Manning et al., 1998), that is, higher levels salivary testosterone are related with lower 2D:4D ratios. Therefore measurement of 2D:4D ratios can provide a non-invasive test for the hormonally controlled bases of human behaviour, cognition, personality and many other individual characteristics.

Digit ratios are normally distributed with ***high degree of overlap*** **across males and females**, but lower ratios are associated with higher exposure to testosterone levels in *utero*



From: Manning, J.T. (2002). *Digit Ratio: A Pointer to Fertility, Behavior and Health,* NJ: Rutgers University Press.

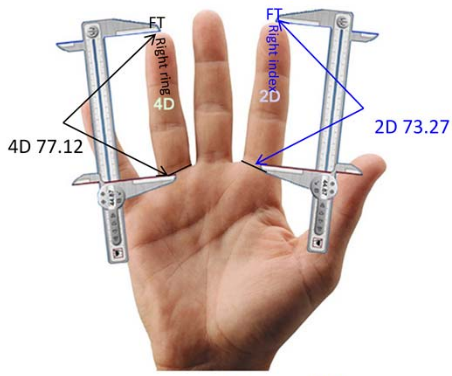
There is, however, substantial overlap between the sexes with respect to digit ratio. It is not uncommon for a man or woman to have a digit ratio that is typical of the opposite sex.

It is believed that there has not yet been any research conducted on the relationship between the 2D:4D ratio and distraction and it appears there is very little research on the relationship between digit ratio and driving behaviour.

How to measure 2D:4D ratio

- The most common measure is the ratio of the index to ring finger (2D:4D) on the right hand. **A relatively longer ring finger – lower 2D:4D – indicates higher prenatal testosterone levels.**

- Measure the distance from the middle of the bottom crease to the tip of the finger. Divide the length of the index finger by the length of the ring finger → 2D:4D ratio



E.g. 2D/4D = 2D:4D
73.27/77.12 =
0.95

Men typically have scores below 1 (average .96), women above 1

Specifically, it is the ratio of the length of the index finger (digit 2, or "2D") and the ring finger (digit 4, or "4D") that is sexually dimorphic**. Generally, males have a ring finger that is longer than their index finger. Females typically have index and ring fingers of about the same length.** The ratio of index finger length to ring finger length is called the “2D:4D digit ratio,” or more simply, the “digit ratio.”

Manning reports that, for males, the index finger is generally about 96 percent of the length of the ring finger, which gives an average digit ratio for males of .96. The digit ratio would be 1.00 if the ring and index fingers were the same length, and greater than 1.00 if the index finger was longer than the ring finger. Males generally have a digit ratio below 1.00 -- they have what is termed a "low digit ratio." Women generally have a digit ratio of about 1.00 (the index and ring fingers are of about equal length), or a "high digit ratio.”

Digit ratio on the right hand is more responsive to testosterone than that on the left hand, as is indicated by the greater sex difference on the right hand than the left.

Our Study: Driving behaviour was assessed under simulated conditions

The driving simulator used in this study was a STISIM Drive **Model 400**.

Participants

- There were 32 male and 44 female participants.
- 58 were university students and 18 were players and associates of a Sydney water polo club.
- Their ages ranged from 18 – 52 years with a mean of 22.7 years.
- All participants held a driver’s license, ranging from 2 to 37 years with a mean of 6.26 years.

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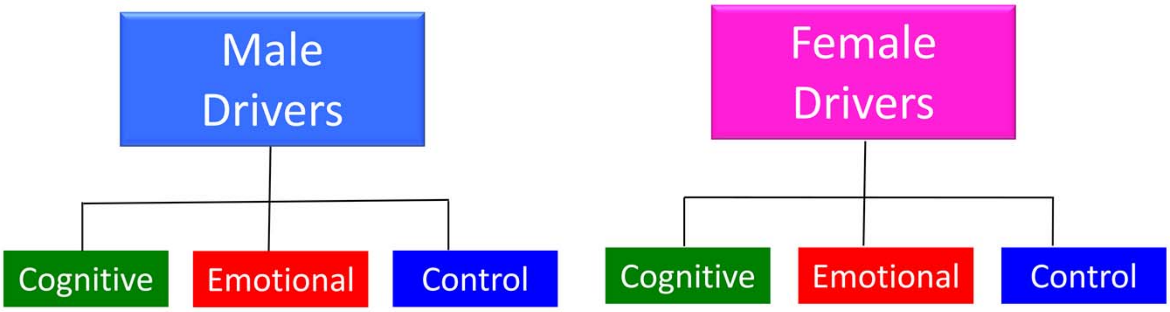
Design of Experiment

The participants were divided into two groups on the basis of their gender and each participant drove the simulator under three different conversation conditions (in counterbalanced order):



Conversation Tasks

Cognitive Conversation - participants were verbally presented with a series of arithmetic problems and spelling words.

Emotional Conversation - participants were verbally presented with three hypothetical moral dilemmas to solve, chosen for their emotional content.

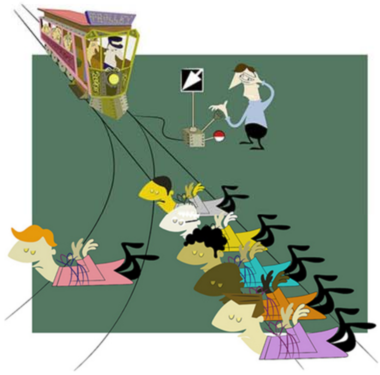
Control Condition - No conversation.

Distractions

Cognitive Distraction:

- E.g. add 68 and 11
- E.g. spell RENEGADE

Emotional Distraction: Three moral dilemmas: were of the "trolley" dilemma genre.



Would you hit a switch to divert a runaway trolley from killing 5 people so that it kills one person instead?

Spelling words chosen form *Collins Cobuild Dictionary*, that classifies words according to their frequency (diamond system) and difficulty (school year)

The moral dilemmas were the same as those used by Irwin, Chekaluk & Geaghan, (2011); and were read out to the participants. They had been selected on the basis of their emotional ratings as given in the Supplemental Data to Greene, Nystrom, Engell, Darley & Cohen (2004). The Neural Bases of Cognitive Conflict and Control in Moral Judgment, *Neuron, 44*, 389-400.

e.g. "Would you hit the switch in order to avoid the deaths of three patients but in doing so cause the death of one?"

Hidden Slide

Audio- presentation of distracting stimuli

An example of how participants wore the headphones on the right hand side of their head during the experiment in order to hear the experimenter

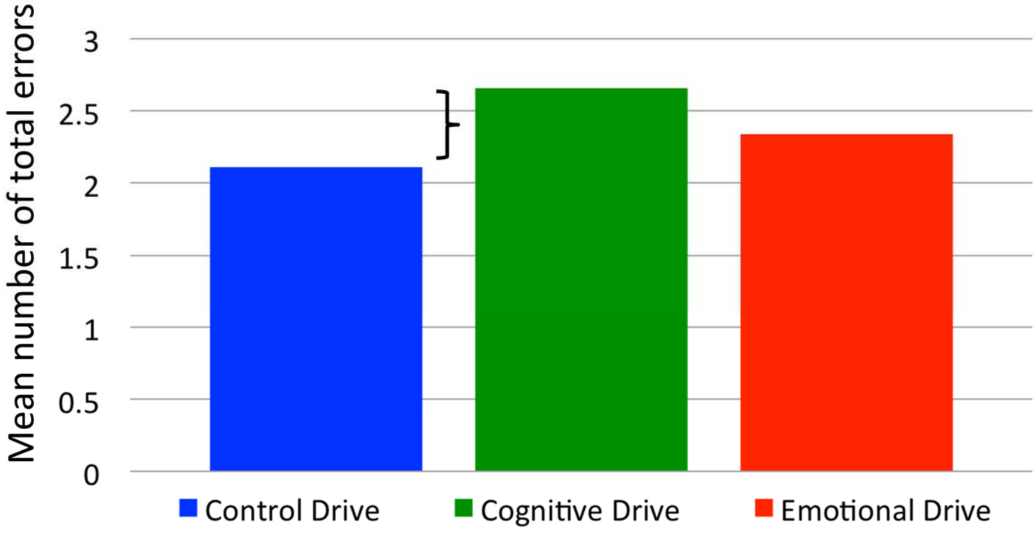
An example of how participants wore the headphones on the left hand side of their head during the experiment to hear car and road environment noises.

The effect of the cognitive and the emotional distractions on participants driving performance was measured by analysing the number and type of driving errors made by the participants, the total time taken to complete drives and the total percentage of time spent over the speed limit in each of the drives.

The effect of the cognitive and the emotional distractions on participants' driving performance was measured by analysing:

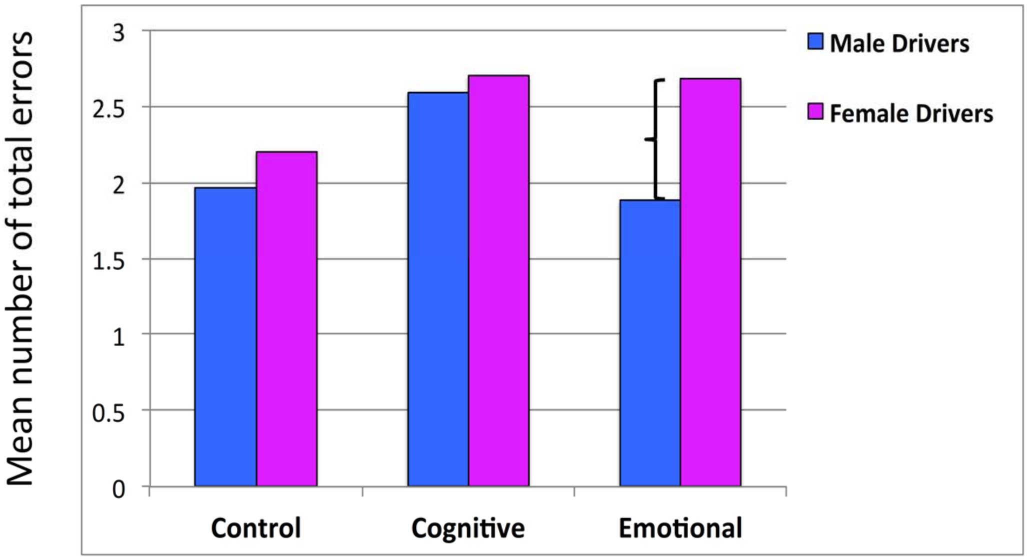
- the *number* and *type* of driving errors
- the total *time taken* to complete the drives and
- the total percentage of *time spent over the speed limit* in each of the drives.

Total Number of Driving Errors: **Conversation Task Differences**



- **Significantly more errors were made in the cognitive drive relative to the control drive**
- No significant difference between cognitive and emotional drives,
- No significant difference between emotional and control drives

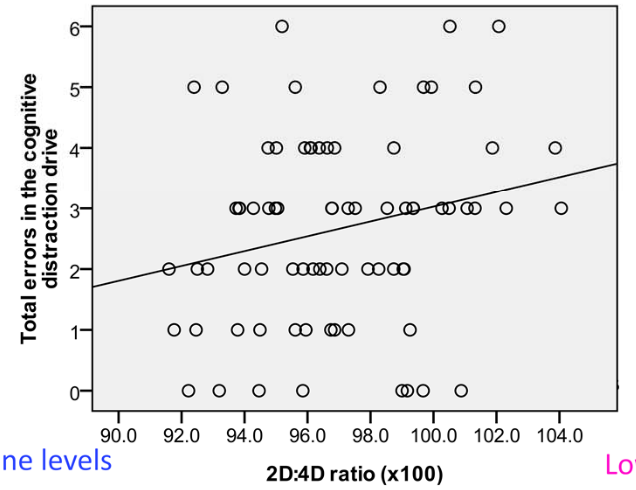
Total Number of Driving Errors: **Gender Differences**



- **Significantly more errors were made by female drivers in the *emotional* drive relative to male drivers**
- No significant differences between male and female drivers in other drive conditions

Total Number of Driving Errors: **Digit Ratio**

Scatter plot of the relationship between **total errors** in the **cognitive distraction drive** and the 2D:4D ratio.



- Significant correlation between total errors in cognitive drive condition: as the 2D:4D ratio increased, so did the number of errors.
- No correlations between digit ratio and errors in the control or emotional drives

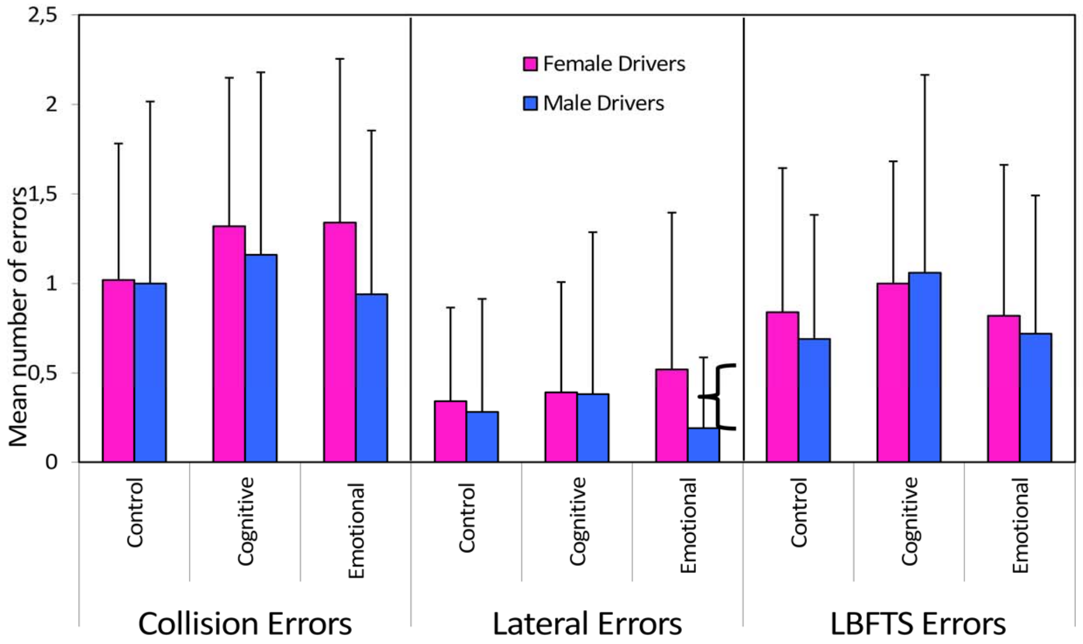
Regression analyses were used to test for interactions between gender and digit ratio for total errors in the cognitive and the emotional distraction drives**. The results for the cognitive distraction drive indicated no significant interaction,** $F(72,1) = .214$, $p = .645$. **The model was then fitted without the interaction term, it was found that digit ratio is significant in explaining number of errors committed in the cognitive distraction drive, $F(73,1) = 4.146$, $p = .045$, independent of gender, $F(73,1) = .162$, $p = .689$.**
The results for the emotional distraction drive also indicated no significant interaction, $F(72,1) = .000$, $p = .983$. The model was then fitted without the interaction term, it was found **that gender is significant in predicting the total number of errors committed in the emotional distraction drive, $F(73,1) = 7.406$, $p = .008$, independent of digit ratio, $F(73,1) = .281$, $p = .598$.**

Types of Driving Error

1. **Collision errors**, indicate *poor response times* to unpredictable events in the drive, as can occur when distracted.
2. **Lateral errors**, indicate reduced *vehicle handling skills* (i.e. difficulty in maintaining lane position on road).
3. **Looked but failed to see errors (LBFTS)**, are indicative of *inattention* as a result of distraction.

1. **Collision errors**, indicate poor response times to unpredictable events in the drive, as can occur when distracted.
   They were calculated by adding up the total number of **reaction time** type errors made by each participant in each experimental condition.
   The total number of collisions with other **cars, pedestrians** and **dogs** made up this type of error.
2. **Lateral errors**, indicate reduced vehicle handling skills. They were calculated by adding up the total number of '**lane position' errors** made by each participant in each experimental condition.
   The total number of **off-road collisions**, **centreline crossings, midline crossings and road edge excursions**
3. **Looked but failed to see errors "LBFTS" errors**, are indicative of inattention as a result of distraction. They were calculated by adding up the total number of 'lapse' errors made by each participant in each experimental condition. The total number of **stop signs missed** and **missed indications** made up this type of error. These error types are consistent with driving performance measures commonly included in driver distraction research (Young et al., 2003)

Driving Errors: **Gender Differences**



Collision Errors

- No sig diffs between any of the drives
- *No gender differences*

Lateral Errors

- No sig diffs between any of the drives
- ***But*** **female drivers made significantly more errors than males in the emotional drive**

LBFTS Errors

- **Sig more errors were made in the cognitive drive than in the other two drives.**
- *No gender differences*

Overall There were no differences within each type of error between male and female drivers, between any of the three drive conditions

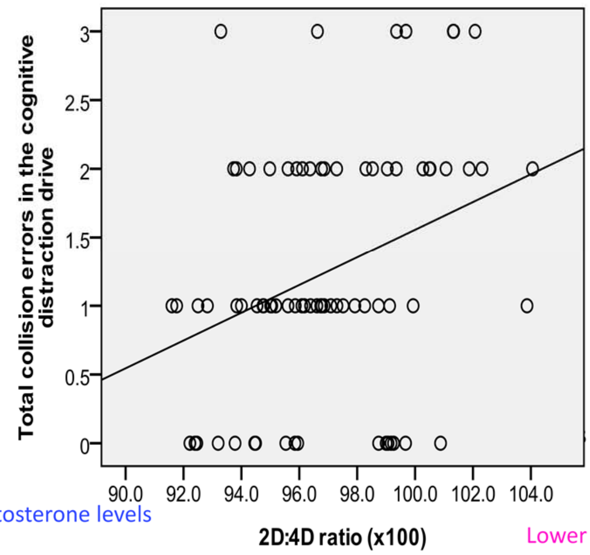
No correlation between lateral errors and digit ratio

- LBFTS errors: Sig diff between **Control** & **Cognitive** drives
- Sig diff between **Cognitive** & **Emotional** drives

Driving Errors: **Digit Ratio**

Collision Errors	Lateral Errors	LBFTS Errors
Significant correlation between collision errors and digit ratio in the cognitive drive only r = .328, p = .004 As the ratio went up, so did the number of collisions! In other words, the more 'androgenised' the driver, the fewer the collisions: Indicative of faster reactions to hazardous events encountered in drive.	No correlation between lateral errors and digit ratio	No correlation between LBFTS errors and digit ratio

Digit Ratio: **Collision** errors in the **cognitive** drive and the 2D:4D ratio



r = .328, *p* = .004

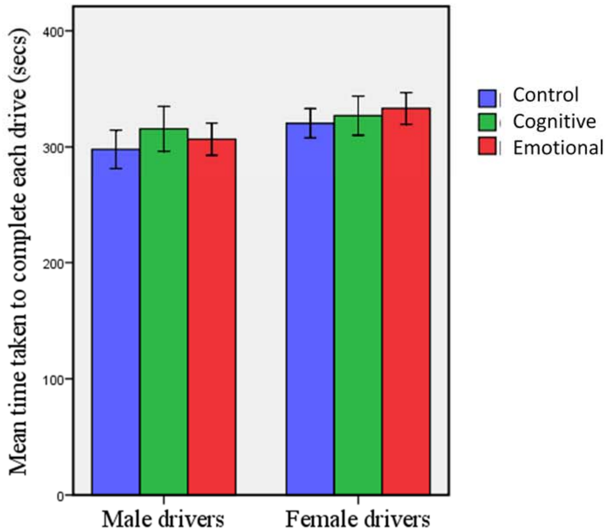
Higher Prenatal Testosterone levels

Lower Prenatal Testosterone levels

Regression analysis was used to test for an interaction between gender and digit ratio for total collision errors in the cognitive distraction drive. The results indicated no significant interaction, $F(72,1) = .000$, $p = .990$. The model was then fitted without the interaction term, it was found that **digit ratio is a significant predictor of collision errors committed in the cognitive distraction drive, $F(73,1) = 8.222$, $p = .005$, independent of gender, $F(73,1) = .049$, $p = .825$.**

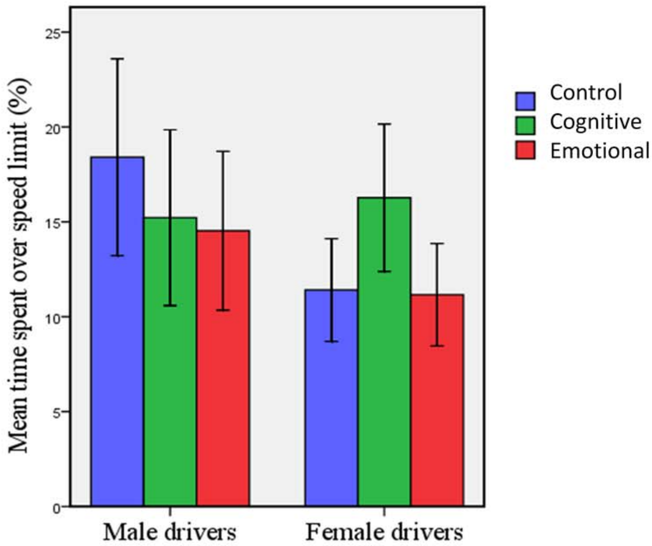
Time taken (in seconds) to complete each of the drives

- Cognitive and Emotional drives took longer than Control drive.
- No difference between Cognitive and Emotional drives.
- Females took longer to do the Control and Emotional drives than males.
- No significant correlations between digit ratio and time taken to complete drives

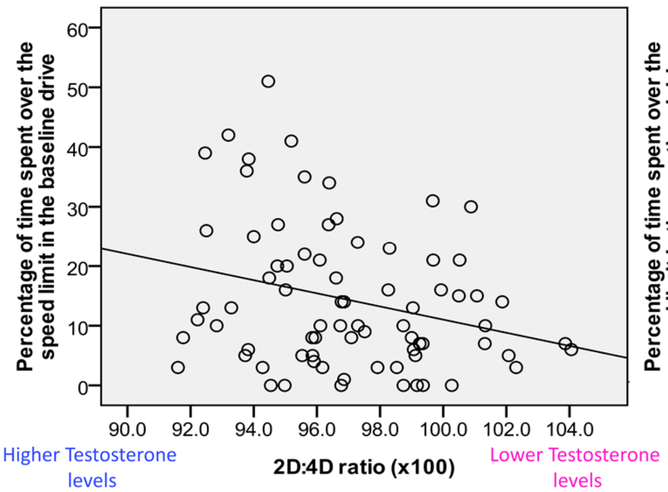


Amount of time spent exceeding the speed limit

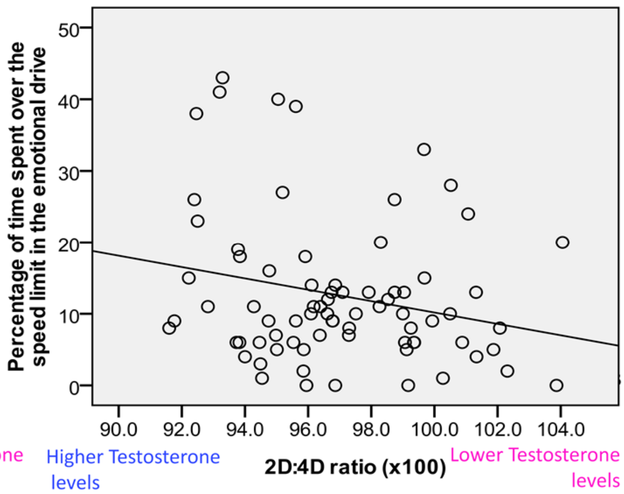
- Speed limit exceeded more often in the Cognitive drive than Emotional drive
- Males spent more time exceeding the speed limit in the control drive.



Digit ratio and exceeding the speed limit



Control Drive $r = -.272$, $p = .017$



Emotional Drive $r = -.231$, $p = .045$

As digit ratio gets lower → more time is spent exceeding the speed limit in both the control and emotional drives, not the cognitive drive.

cf no gender difference in cognitive drive; but digit ratio is correlated with number of errors in cognitive drive

Gender is significantly correlated with digit ratio

The relationship between gender and digit ratio was analysed using an independent samples t-test. A significant gender effect was found, $t(74) = -3.107$, $p = .003$, as predicted females had significantly higher digit ratios than males.

Summarising the speeding findings:

- Distracting drives took longer (less speeding)
- Female drivers took longer when emotionally distracted (as well as made more errors), and exceeded the speed limit more often in the cognitive drive.
- Male drivers exceeded the speed limit more often when *not* distracted.
- As digit ratio got lower (higher prenatal T), more time was spent exceeding the speed limit in the Control and Emotionally distracting drives.

To summarise the distraction findings:

- Overall more driving errors were made in the **Cognitively** Distracting drive.
- **2D:4D ratio was negatively correlated with number of errors in the Cognitive drive**:
  - **i.e. *More*** prenatal T → **fewer** driving errors were made
    - The type of errors made (Collisions) suggests that testosterone is implicated in speed of responding to unexpected events in the drive.
- **Gender difference in Emotional Drive**:
  - **Females made more errors than males in the emotional drive**

When errors are broken down into type of errors made:
Reaction time errors:
No differences between distraction conditions
No gender differences;
But as 2D:4D ratio increases → more errors are made
Vehicle handling errors:
No differences between distraction conditions
But Female drivers → more errors in emotional drive;
No relationship with digit ratio
Inattention errors:
Cognitive drive → more errors than other two drive conditions
No gender differences
No relationship with digit ratio

Summarising the findings: **Distraction Conditions**:

- **Cognitive** drive: → more errors
- Errors in this drive condition were correlated with **digit ratio** – but not gender
  - Digit ratio: not associated with time spent exceeding the speed limit
- **Emotional** drive: Errors in this drive condition were correlated with **gender** – but not digit ratio
  - Female drivers drove more slowly and still made more errors, especially the vehicle handling type of errors!
  - Digit ratio was negatively associated with exceeding the speed limit in this drive condition.

Summarising the findings: **Gender**

- Is associated with making **more errors under emotionally distracting** conditions
  - Psychosocial factors may lead women to become more socially engaged with the person to whom they are talking than do men, as suggested by Irwin, Chekaluk and Geaghan (2011).

- **speeding** under non-distracting conditions (Control Drive):
  Males drive faster than females

Summarising the findings: **Digit Ratio**

- Is associated with amount of time spent exceeding the speed limit (regardless of gender)
- Is associated with number of errors made in the cognitively distracting condition (regardless of gender)

What roles do gender and testosterone play?

•**Being female** → more errors when emotionally involved in conversation
  •Psychosocial factors may lead women to become more socially engaged with the person they are talking to than men.

•**Being male** → drive faster, particularly under no distraction conditions

•**Testosterone (2D:4D ratio)** → associated with exceeding speed limits more often.

•But → less distracted by cognitive tasks.

In Conclusion

Does testosterone level reduce distraction errors?

It would seem that testosterone does play a role in facilitating reaction times to hazardous events, under cognitively distracting conditions, but would need to – to compensate for the higher speeds that these drivers may be travelling at!

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