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Te Whare Wānanga o Waikato

The effect of geometric and arithmetic progressions on demand for food under concurrent progressive-ratio and fixed-ratio schedules

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Research Aims:

- Identify whether procedural differences will affect the demand foods in the brushtail possum
  - Schedule type – PR FR, PFR FR
  - Progression type – Geometric, Arithmetic
  - Food type – wet and dry
- Use of exponential (Hursh & Silberberg, 2008) and cross price demand (Hursh et al., 2013) models to analyse results

Exponential Demand Model

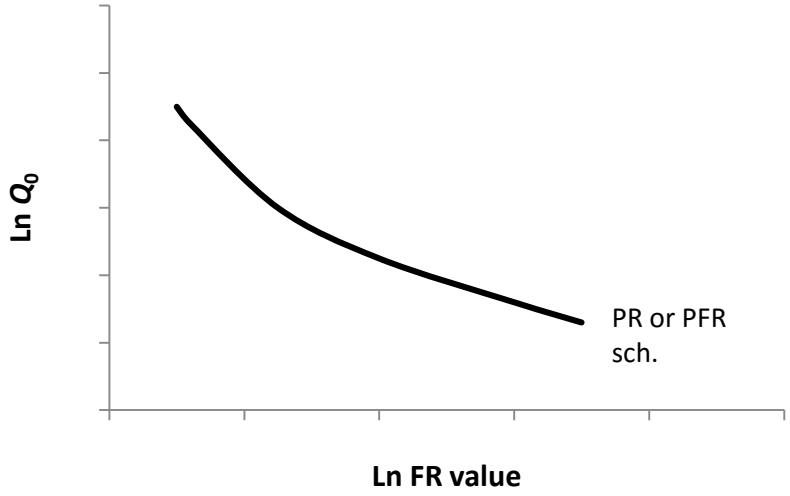
$$\ln(Q) = \ln(Q_0) + k(e^{-aQ0C} - 1)$$

Q_0 represents the y-intercept termed initial demand

α is the rate of change of elasticity as ratio requirement increases, termed 'essential value',

k is the range of the dependent variable

C is the ratio requirement (Hursh & Silberberg, 2008)



Cross-Price Demand Model

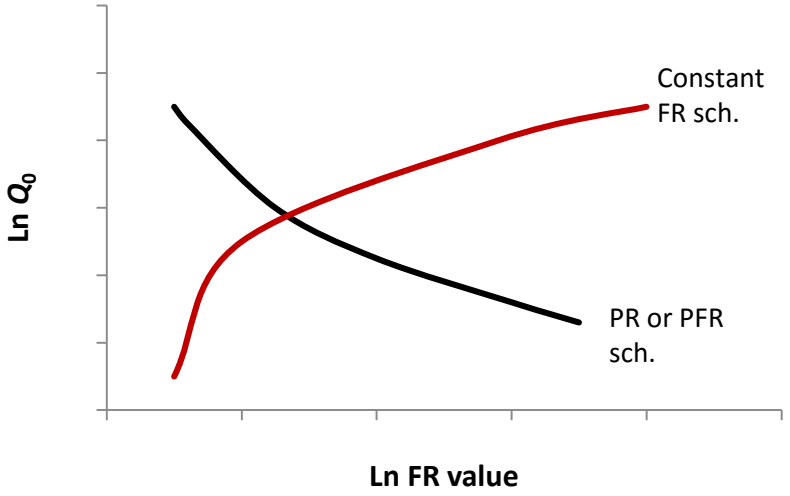
$$Q = \ln(Q_{\text{alone}}) + Ie^{-\beta.C}$$

Q_{alone} is when the price of the reinforcer under the incrementing schedule is zero is

I is the interaction constant

β is the sensitivity of consumption rate under the alternative schedule to changes in price of the incrementing schedule (Hursh et al., 2013).

- When I is negative = commodities are substitutable.
- Higher values of β = Consumption of alternative *more sensitive* to changes in price of the other (incrementing) schedule



Demand Curves

- Demand curves for consumption under the incrementing schedule AND the FR schedule*

  *FR consumption rate is measured as per the PR trial duration.

Dependent variables

- Estimates of demand: Initial demand, essential value and P_{max}

$$P_{max} = \frac{0.65}{\alpha . Q_0 . k^{1.191}}$$

  - P_{max} = ratio where responding shifts from inelastic to elastic demand or point of maximal responding

- Break point
  - Last complete ratio

- Cross point
  - Point of intersection between demand curves
  - Look at perseverative and conservative cross points

Background – Schedule Type

- Use of concurrent schedules, one incrementing and one constant.
  - PR – ratio requirement increases after each rft *within* each session
  - FR – ratio requirement remains constant throughout a session
  - PFR – ratio requirement increases *across* schedules

Background – Schedule Type

- PR and PFR schedules show similar accounts of demand

= decrease in consumption [rate] as ratio requirement increases

  - Break points are higher under xx schedules compared to xx schedules
  - Initial demand is xxx

PR vs FR

Background – Schedule Type

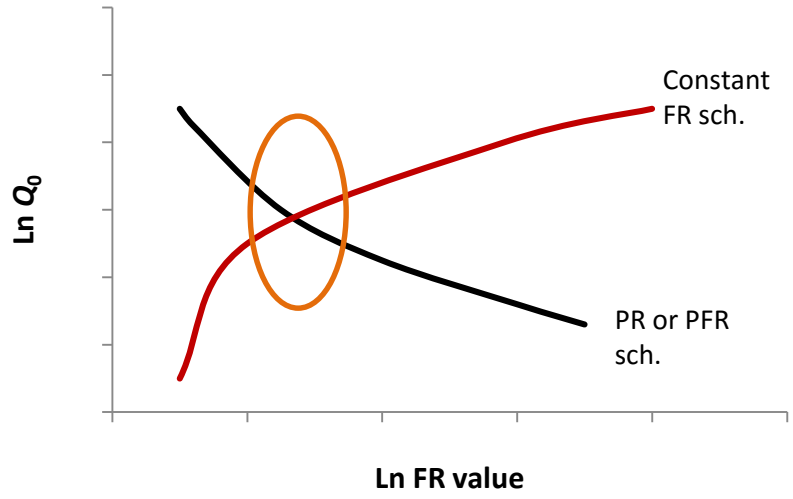
Concurrent PR FR and PFR FR – foraging literature

- Incrementing schedule = patch with depleting resources
- Constant FR = 'traveling' between patches(Wanchisen, Tatham & Hineline, 1988)

- Use the cross point to look at

the effect of price… and food type:

- If greater than the point where the two schedules are equal (equivlalence point) = perseverative
- If smaller than the point where the two schedules are equal (equivlalence point) = conservative



Background – Schedule Type

Same foods available under PR FR schedules:

- Chimps – concurrent arithmetic PR FR incrementing by 20 responses maximized rft rate by switching from PR to FR when ratios were the same (Hineline & Sodetz, 1987; Hodos & Trumbule, 1967)
- Pigeons switched from PR to FR when ratio requirements (step size of 20) were equal or when the PR was slightly higher – perseverative (Wanchisen et al., 1988)
- Pigeons – with small steps switched from PR to FR at lower values than equivalence point – conservative (Neuman et al., xxxx).

Background – Schedule Type

Different foods available under PFR FR schedules:

- Measure the demand for different types of water in rats (Holm, Ritz, & Ladewig, 2007; Sørensen et al., 2001) and substrate in pigs (Holm, Jensen, Pedersen & Ladewig, 2008; Pedersen, Holm, Jensen, & Jørgensen, 2005).
- Cross points on the demand curves were generally higher than the equivalence point for preferred commodities under the PFR schedule

= perseverative cross points for the more 'preferred' food

Rats and pigs will work harder to obtain a favoured commodity than obtain the alternative for less work.

Background – Progression

- No best practice
- Killeen, et al. (2009) and Stafford et al. (1998) suggest the use of geometric to obtain results faster
  - Arithmetic: step size of a fixed value – e.g., 5
  - Geometric: multiples of a fixed value – e.g., 2; doubling
  - Polynomic: Killeen -
- Response rates differ across progression
  - Arithmetic progression
    - Response rates increased during the first few ratios prior to a peak. Response rate then declined linearly
  - Geometric progression
    - Sharper increase in response rate than the arithmetic progression followed by a steeper decline before continuing at a low rate to high ratios

Background - Progression

- graphs

Background - Progression

- The affect of different progressions on break point:
  - Killeen et al. (2009) and Stafford & Branch (1998) found break points were larger under geometric than arithmetic progressions in pigeons
    - large step-sizes of geo compared to uniform of arith
    - Prior and current ratio influences behaviour – large jump in ratio requirement in the geo affects adaptation to the next = variable behaviour
    - Killeen et al. used a *repetitive* PR procedure – increased ratio requirement every 6th ratio – responding was consistent rate at low ratios but varied at high ratios concluding that adaptation to high ratios takes longer than to low ratios.
  - When the step sizes were small (1-3 responses) there was no difference in break point (Killeen et al., 2009; Stafford & Branch, 1998).
  - Cavarrubias & Aparicio (2008) – found break point increased with small step size.

Background - Food

- Single- and paired preference assessments
  - Preference for berries, egg, and locust.

- Demand: Previous concurrent experiments
  - Higher demand for egg and chicken over berries and mushroom
  - Higher break point and cross points for preferred foods

Predictions

- Determination of demand for foods will be the same across schedule and progression type for each food
- Response rates and consumption should be similar under the PR FR and PRF FR schedules.
- Break points and cross points will be higher under the geometric progression as step-sizes are larger than under the arithmetic progression.

Method

- 12 possums – two groups (P1-P6, P7-P12)
- All participated in previous taste preference experiments
  - All = single- and paired- preference assessments
  - P1-P6 = demand experiments
- The experiment was conducted in the morning and the possums were given supplementary feed in the afternoon.
- Constant access to water
- Kept in reverse day/night cycle – lights off at 9am.

16 Conditions

- Schedules
  - PR FR 30
  - PFR FR 30

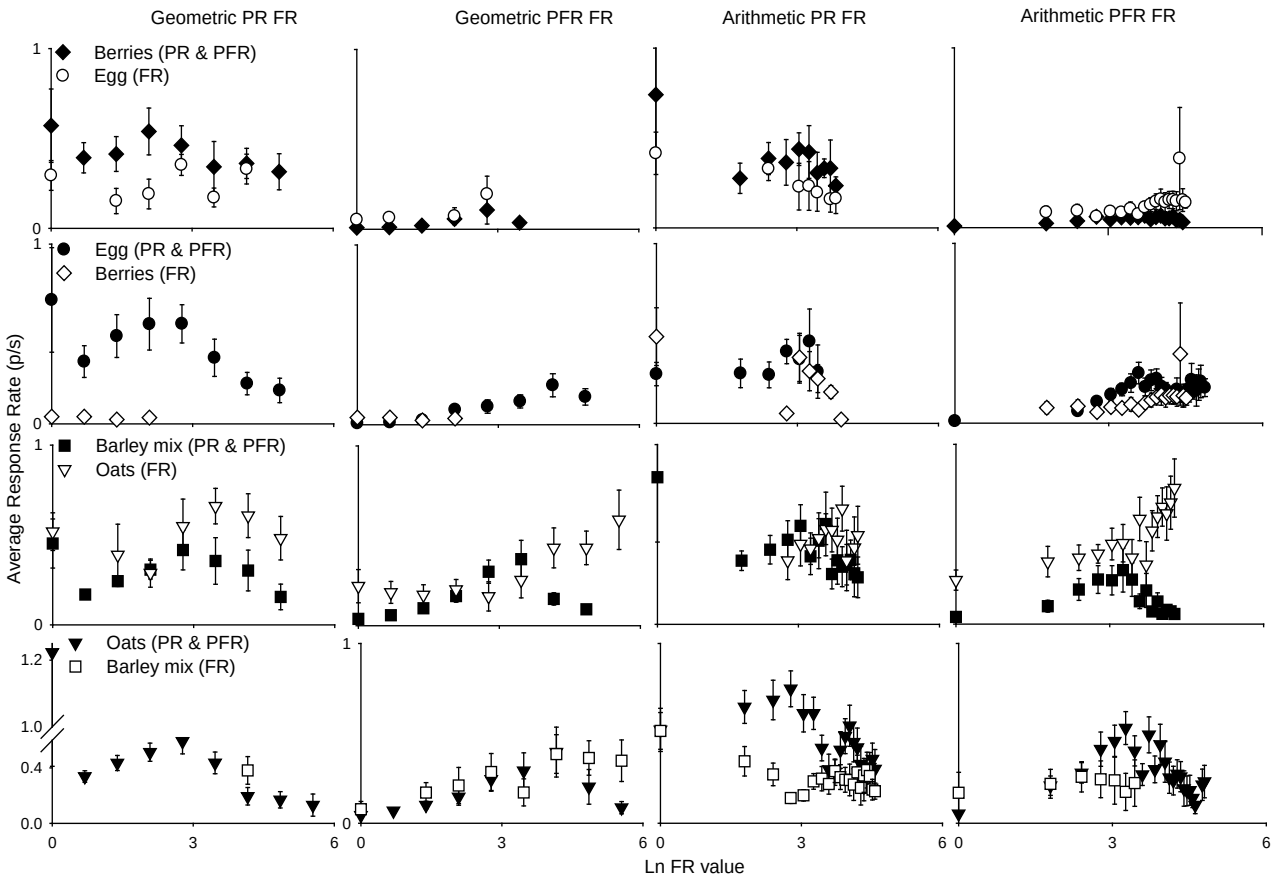
- Progressions
  - Geometric – doubling: 1, 2, 4, 8, 16, 32…
  - Arithmetic – step size of 5: 1, 6, 11, 16, 21, 26, 32…

- All foods tested under the PR/PFR and FR schedule within each pair
- Berries and Egg, and Oats and Barley/Cocopop mix
  - All foods tested under the PR/PFR and FR schedule within each pair
  - Two wet food pairs and two dry food pairs

Results – Response Rates

- Schedules
  - PR FR – response rates were high at the lowest ratio and then decreased with increases in ratio requirement
  - PFR FR – response rates were initially low before increasing to a peak, then declining
    - Possibility of FR 1 artifact giving high response rates
  - Increases in FR response rates under PR/PFR
- Progression
  - Lower peaks in response rate for foods under geometric compared to arithmetic
- Foods
  - Similar across foods

Results – Response Rates



Average response rate (p/s) as a function of ln FR value for all foods under the geometric and arithmetic progressions of the PR FR and PFR FR schedules. Filled symbols correspond to foods under the PR or PFR schedule, and the unfilled symbols correspond to foods under the FR schedule. Response rates were presented when more than five possums contributed to each data point.

Results – Breakpoint

- Schedules
  - Higher break point under PR FR schedules compared to PFR FR schedules
- Progression
  - Significantly higher break point under geometric progression compared to arithmetric
- Foods
  - Egg had highest break point, then berries, oats and barley

Results – Consumption Rate

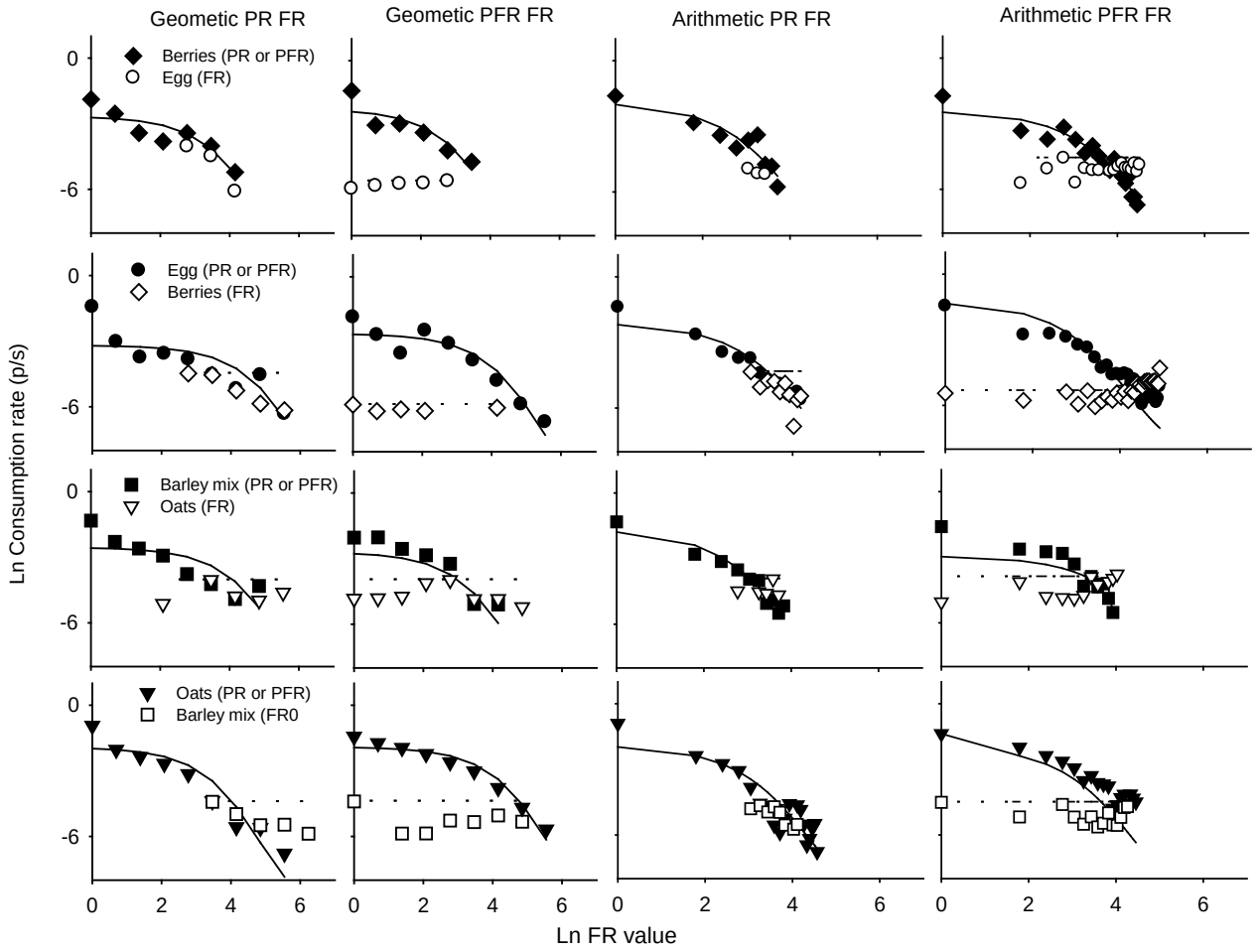
- Exponential model fit well
  - VAC 88.1% (σ =8.2) for PR FR
  - VAC 98.3% (σ =1.6) for PFR FR
- Consumption rate declined as ratio requirement increased under PR and PFR schedules
- Consumption rate increased under the FR schedules
- Rfts were earned earlier under the FR schedule of the PFR FR compared to earlier than PR FR.
- More ratios completed under arithmetic progression than geometric progression

Results – Consumption Rate

- Cross-Price model fit well
  - VAC 97.8% (σ = 5.1) for PR FR
  - VAC 85.0% (σ = 14.2) for PFR FR

- Estimates of the interaction parameter = negative
  - indicating the relationships between foods on the incrementing and constant schedules were substitutable.
  - more substitutable under PR FR than the PFR FR schedules
  - There was less sensitively of consumption under the FR schedule to changes in PR schedule under the arithmetic progression.
  - Barley and oats appeared to be more substitutable for each other than berries and egg.

Results – Consumption Rates



Average ln consumption rate (p/s) plotted as a function of ln FR value for all foods under the geometric and arithmetic progressions of the PR FR and PFR FR schedule conditions. Filled symbols correspond to foods under the incrementing FR schedule, and the unfilled symbols correspond to foods under the FR schedule. The x-axis of the arithmetic graphs (Columns 3 & 4) are stretched to view the pattern of the data points. All consumption rates were presented to illustrate the trends of the data.

Results – Estimates of Demand

Q_0 – no sig difference between schedule, progression or food.

- Schedules:
  - Q_0 under PR FR generally greater than -1, PFR FR generally less than -1
- Progression:
  - Q_0 under arithmetic generally greater than -1, geometric generally less than -1
- Food
  - Lowest Q_0 estimate for egg

Results – Estimates of Demand

α - sig difference between schedule, progression or food.

- Schedules:
  - α of PFR schedule significantly different and closer the 0 than PR
  - α of PR sig higher and more variable than PFR
- Progression:
  - Essential values in the geometric PR FR schedules were significantly lower than essential values in the geometric PFR FR schedules [t (47) = 2.42, p = .019, d = 0.35].
  - Similarly, the essential values in the arithmetic PR FR schedules were significantly lower than the arithmetic PFR FR schedules [t (47) = 3.37, p = .002, d = 0.49].
- Food – order of magnitude for α (closest to zero)
  - Under the arithmetic prog: Oats, barley, berries, egg
  - Geo: oats egg, berries, barley

Results – Estimates of Demand

- P_{max} – no sig difference between schedule, progression or food.
  - Varied widely and some estimations were negative
  - With values excluded (FR 1.8 – 13.8)
  - Largest value for egg under geometric PFR FR and barley under arithmetic PR FR.

Results – Cross Point

- Schedules:
  - Higher under the PFR FR schedules (64) compared to PR FR (13) (not sig)
- Progression:
  - Significantly higher under the geometric (45) than arithmetic progression (34)
- Foods:
  - Average cross points were perseverative – greater than the point of equivalence (30)
  - Highest for Egg but cross points were also high for barley

Discussion

- Response rates
  - Similar in the geometric and arithmetic PR FR schedules resembling the geometric pattern
  - Similar in the geometric and arithmetic PFR FR schedules resembling the arithmetic pattern

- Highest break points found under geometric progression
  - Other researchers found that break points were higher when progressions had larger step sizes (Covarrubias & Aparicio, 2008; Killeen et al., 2009)
  - Small increases session to session under arithmetic progression a s found by Killeen et al. (2009)

Discussion

- Expected consumption rate patterns as found by previous authors (Baron & Derenne, 2000; Foster et al., 1997, Stafford & Branch, 1998)

Demand measures differ in description of demand

- Initial demand
  - Foods that appear to be more highly preferred - Egg - have lower initial demand values
  - This is similar to the findings of Foster et al. (2009) and Hursh et al. (1988).

- Essential value
  - Differed across schedule, progression and food
  - Consistent with statements by Foster et al (2009), Grant et al. (2014) and Hursh et al. (1988) that essential value should be different for foods.

Discussion

- Cross points were perseverative
  - Higher cross points under PFR FR
    - Suggests possums did not maximize their rft rate under either incrementing or constant schedules
    - In contrast, under the PR FR schedule cross points were only slightly higher than equivalence point – (Wanchisen et al., 1988) = maximizing rft rate
    - Similar results to Holm et al., (2007) and Sørensen et al., (2001) where rats would respond to higher values under the incrementing schedule for a preferred water type when another type was available for a constant price.
  - Arith progression = more subsitutable relationships
  - But cross points were lower under the arithmetic PR FR compared to others
    - Unclear – not about number of rfts as this was controlled in the selection of the arith increment
    - More likely because the first ratio after the equivalence point under the geometric progression is large and the possums continued to respond as an artefact of the previous rft to higher ratios before switching

Conclusion

- Using different schedules and progressions changes the conclusions we draw regarding the demand for foods.

- A cross point analysis provides the most information about the interaction of demand for food as a function of price and availability.

- Generally when preferred foods were available under the PR or PFR schedule, higher cross points were observed and were lower when a preferred food was available under the constant FR schedule.

Last Word…

- This experimental series involved two preference assessments and four demand experiments involving up to eight food types.

- It is clear that possums have individual food preferences – just like us.
- They will work harder for foods they consider preferred.
- Although they will respond for *any* food type if available at a low price

Possums are NZ's most pervasive pest.

Cross Point Demand

- The point at which responding on the schedules changes is called the ‘cross point’.
- Cross point demand identifies the ‘nature’ of the demand interaction between the two foods when available at varying prices (Hursh, 1980).
- We expect to see mostly elastic demand typical of an open economy as there are supplementary food sources outside the experiment (Hursh, 1980)

Conclusion

- Some possums will eat meat and egg if there is opportunity
  - Which means major implications for our NZ flora and fauna
- Possums will generally put more effort into gaining access to foods they prefer
- Food preferences are unstable. There may be an effect of exposure to foods.

Thank you!

Frank

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