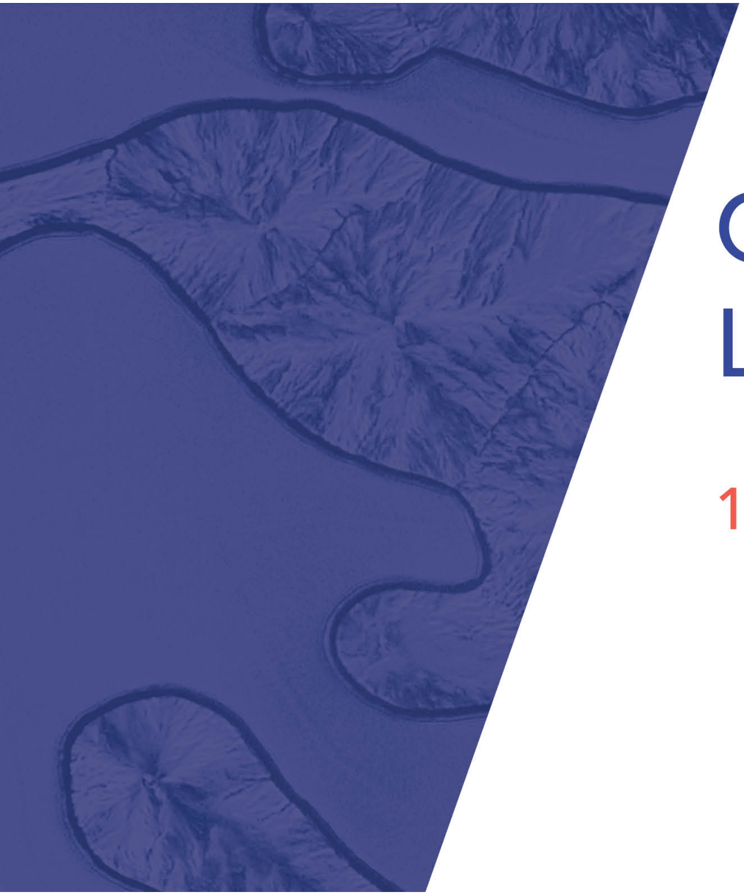
Welcome to Today's Webinar!



COLOR COMMUNICATION THROUGH LEXICAL COLOR CATEGORIES

17 September 2021 • 12:00 EDT (UTC -04:00)

OSA Color Technical Group

Technical Group Executive Committee

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Chair of the OSA Color Technical Group

Manuel Spitschan
University of Oxford

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Universidad de Granada

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University of South-Eastern Norway

About the Color Technical Group

Our technical group focuses on all aspects related to the physics, physiology, and psychology of color in biological and machine vision.

Our mission is to connect the 900+ members of our community through technical events, webinars, networking events, and social media.

Our past activities have included:

- Special webinar on display calibration
- Vision science in times of social distancing coffee breaks
- Incubator meetings

Connect with our Technical Group

Join our online community to stay up to date on our group's activities. You also can share your ideas for technical group events or let us know if you're interested in presenting your research.

Ways to connect with us:

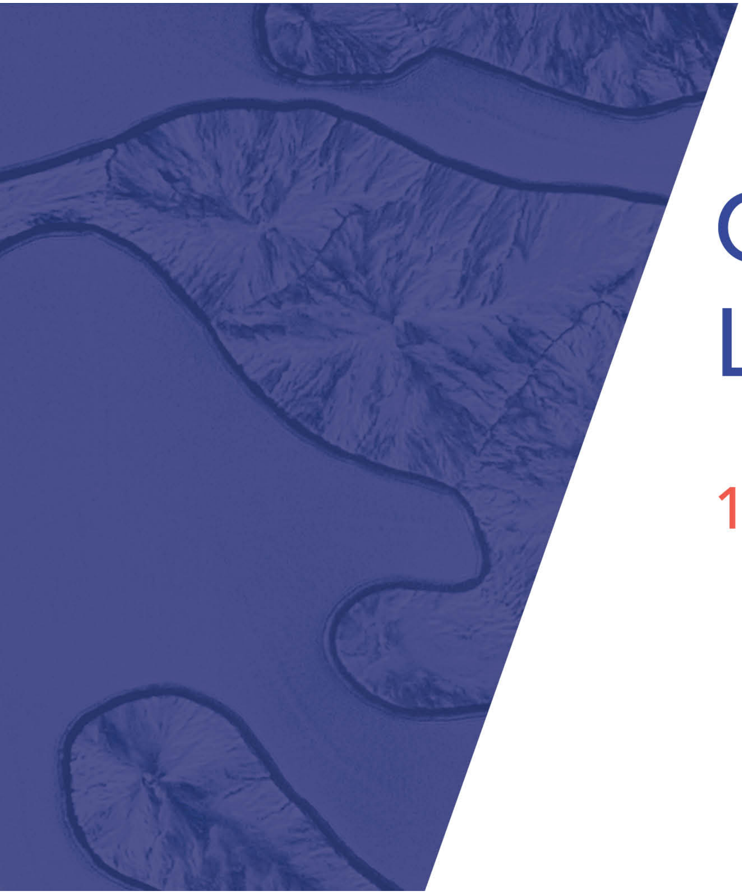
- Our website at www.osa.org/vc
- On Twitter at #OSAColorTG
- On LinkedIn at www.linkedin.com/groups/13573604
- Email us at TGactivities@osa.org

Another webinar in 10 days:

OPTORETINOGRAPHY: PAST, PRESENT AND FUTURE

27 September 2021 • 13:00 EDT (UTC -04:00)

OSA Color Technical Group

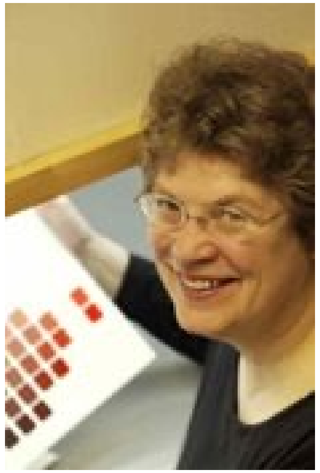


COLOR COMMUNICATION THROUGH LEXICAL COLOR CATEGORIES

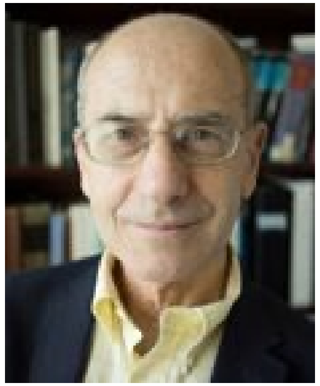
17 September 2021 • 12:00 EDT (UTC -04:00)

OSA
Color
Technical Group

Today's Speakers



Angela M. Brown
Ohio State University



Delwin T. Lindsey
Ohio State University

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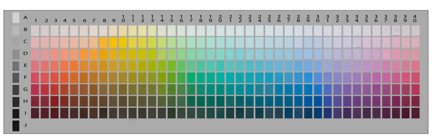
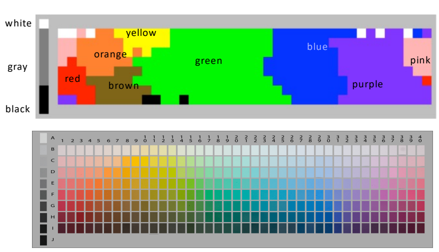
World Color Survey Chart - 330 Munsell samples



Kay, Berlin, Maffi, et al. (2009)

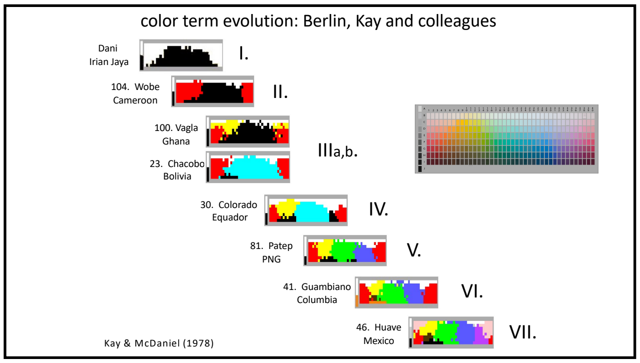
2

One individual English speaker's color terms

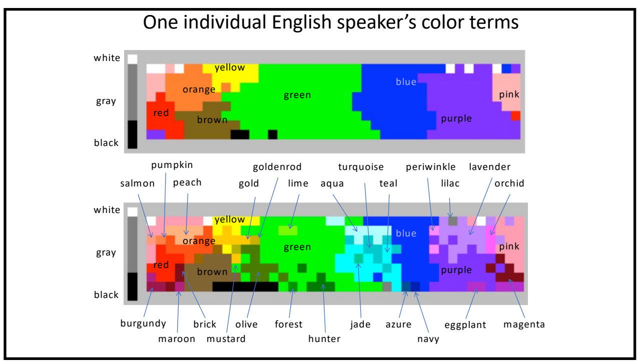


Lindsey & Brown (2014)

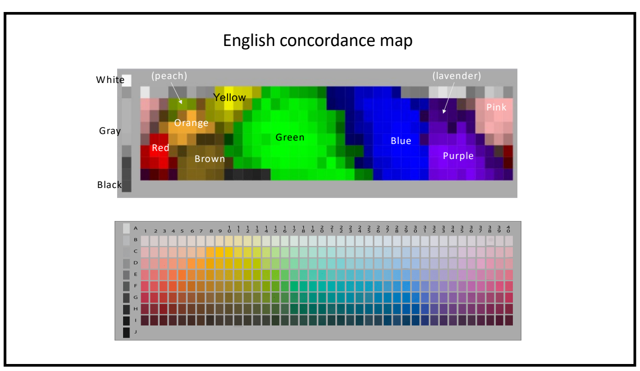
3


color term evolution: Berlin, Kay and colleagues
Dani
Irian Jaya
I.
104. Wobe
Cameroon
II.
100. Vagla
Ghana
23. Chacobo
Bolivia
IIIa,b.
30. Colorado
Equador
IV.
81. Patep
PNG
V.
41. Guambiano
Columbia
VI.
46. Huave
Mexico
VII.
Kay & McDaniel (1978)

4

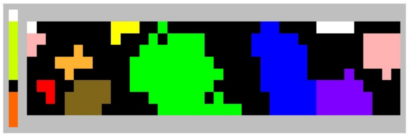

One individual English speaker's color terms
white
gray
black
yellow
orange
red
brown
green
blue
purple
pink
pumpkin
salmon
peach
goldenrod
gold
lime
turquoise
aqua
teal
periwinkle
lilac
lavender
orchid
burgundy
maroon
brick
mustard
olive
forest
hunter
jade
azure
navy
eggplant
magenta

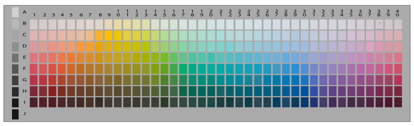
5


English concordance map
White
Gray
Black
(peach)
(lavender)
Yellow
Orange
Red
Brown
Green
Blue
Purple
Pink

6

Only 51% of samples named with same term by 80% or more of informants





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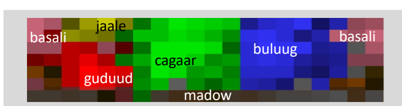
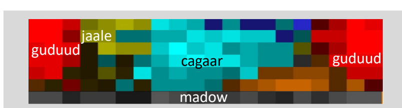
Two Somali concordance maps

GB Motif



Grue Motif



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overview

- The color communication game (CCG)
- Basic principles of Information Theory the underlie the design and analysis of CCG
- CCG simulation using color naming data only
  - English and Somali informants
- CCG in practice – color choices based in sender names
  - English and Somali informants
- Closing remarks

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The color communication game (CCG)

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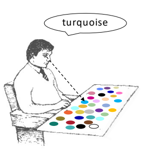
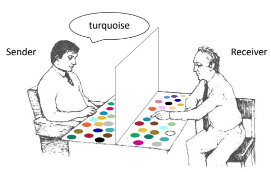
The Color Communication Game:





Entropy: $H = -log_2(\frac{1}{N})$ bits.

$H = -log_2(\frac{1}{16})$ = 4 bits.

Mutual Information: $I(S,R) = H(R) - H(R \mid S)$

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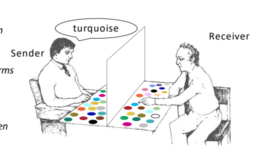
Color communication game

- Wittgenstein (1954). *Philosophical Investigations*, "language games"
- Shannon & Weaver (1948). *A Mathematical Theory of Communication*
- Lantz & Stefflre (1964). *"Communication accuracy"*
- Baddeley & Attewell (2009). *Information theoretic study of English terms for lightness*
- Jameson & D'Andrade (1997); Regier, et al (2015). *Color lexicons optimally "informative"*
- Rosch (1972); Zaslavsky, et al. (2017,18). *Cost/benefit tradeoff between informativeness and complexity*
- Zaslavsky, et al. (2019). *Color lexicon is a communication channel*
- Gibson, et al. (2017). *Color lexicon and communication need.*



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"What color have I selected?"

$H = -log_2(\frac{1}{4})$ = 2.0 bits.

message	Chances of selecting correct square	improvement	bits
none	1/4		
"green"	1/2	2 x	1
"red"	1/1	4 x	2
"chartreuse"	1/4	1 x	0
	1/1	4 x	2

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Mutual Information

$$I(C_s, C_r) = \sum_{s,r \in C} p(s,r) \log_2\left(\frac{p(s,r)}{p(s)p(r)}\right)$$

receiver

sender

	"red"	"pur."	"char."	"grn"
"red"	1/4			
"pur."		1/4		
"char."			1/4	
"grn"				1/4

I = 2.0 bits

	"red"	"pur."	"grn."	"grn"
"red"	1/4			
"pur."		1/4		
"grn."			1/8	1/8
"grn"			1/8	1/8

I = 1.5 bits

	"red"	"pur."	"grn."	"grn"
"red"	1/4			
"pur."		1/4		
"char."	1/16	1/16	1/16	1/16
"grn"			1/8	1/8

I = 1.28 bits

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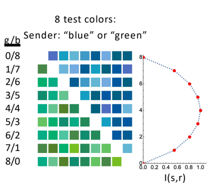
Mutual Information

$$I(C_s, C_r) = \sum_{s,r \in C} p(s,r) \log_2\left(\frac{p(s,r)}{p(s)p(r)}\right)$$



- Mutual information depends upon both s/r idiolects *and* size and composition of the test color palette.
- In general, MI increases as s/r color vocabularies increase
- MI will be optimal when s/r idiolects are equivalent and color terms are equally distributed across palette:
  $I = \log_2 (N_{terms})$ == Channel Capacity
- *This is the best possible outcome in the CCG.*

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Where is information lost?

(Set by the stimulus set) "Theoretical maximum:" $I = log_2(N_{samples})$

(Set by the number of terms) "Best possible" for lexicon: $I = log_2(N_{color\ terms})$

Set by terms and category sizes — "Selfie:" Sender and receiver are idiolects are the same.

(human behavior)

"Solitaire:" Human receiver, using own color messages.

"Interpersonal:" Human receiver, using a different person's color messages.

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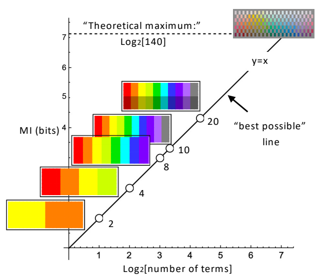
The constraints on receiver performance:

"Theoretical maximum:"
MI = Log_2[nSamples]

"Best possible" performance ("channel capacity"):
MI = Log_2[nCategories]
= Log_2[nTerms]



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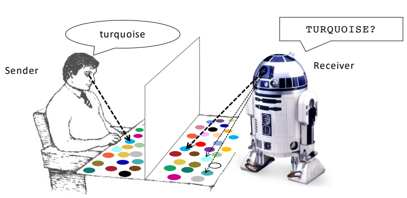
The Color Communication Game:

"Selfie:" the robot-with-sender's-dictionary



The robot chooses its response, randomly, among alternatives in the sender's dictionary entry.

R2D2 image is from wikipedia

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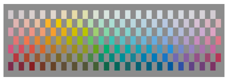
"Dictionary" is from color-naming data.

Somali language data

Subjects: non-English speakers
Stimuli: Munsell papers



English language data

Subjects: University people
Stimuli: Munsell papers

One-term data*: one term per sample.

Two-term data: two terms per sample.
Terms concatenated into unique composite terms.
Experimentally manipulate the size of the lexicon.

*Somali: JoV 2016; English: JoV 2014.

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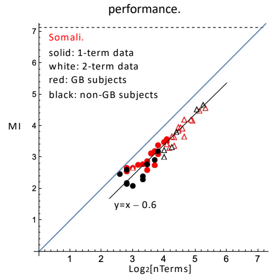
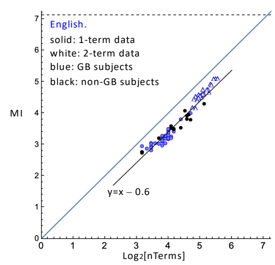
Robot using Somali and English dictionaries

When individuals and groups use more terms, their dictionaries do better, but the robot always loses about a half-a-bit compared to "best possible" performance.





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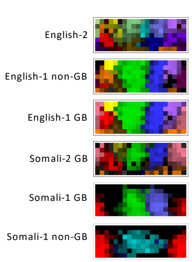
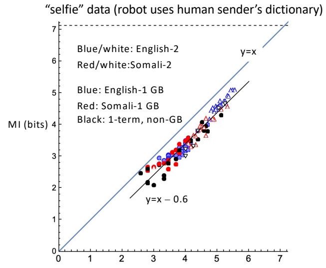
Human categories lose MI because human dictionaries define categories of different sizes.



"selfie" data (robot uses human sender's dictionary)



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Where is information lost?

(Set by the stimulus set) — "Theoretical maximum:" MI = Log_2[nSamples]

↓

(Set by the number of terms) — "Best possible" for lexicon MI = Log_2[nTerms]

Loss ~ 0.6 bits

↓

(Set by the distribution of terms) — "Selfie:" Robot is receiver using the sender's dictionary.

↓

(human behavior)

"Solitaire:" Human receiver, using own color messages.

↓

"Interpersonal:" Human receiver, using a different person's color messages.

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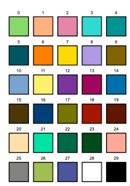
Experiment: naming ("word-for-color"), identification ("color-for-word").

- Each person named each color (word-for-color)
- Then identified colors based on the color terms from themselves or from somebody else (color-for-word).
- 31 English speakers were tested in groups, i-Pads in linked network.
  - First round as "naïve" participants, others in group provided terms.
  - Second round as "experienced" participants.
- 89 Somali speakers played the game once, against a single other Somali speaker.



30 samples. Calibrated I-Pads, presented singly (word-for-color) or in array (color-for-word).

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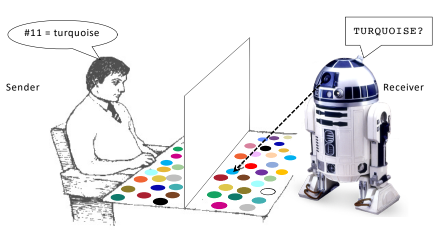
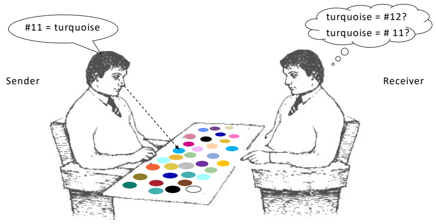
This color communication game can be played as a "selfie" (against the robot)



R2D2 image is from wikipedia

24

This communication game game can be played as "solitaire" (against oneself)



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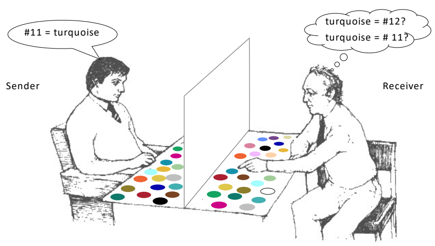
This communication game game can be played "Interpersonally" (against someone else)



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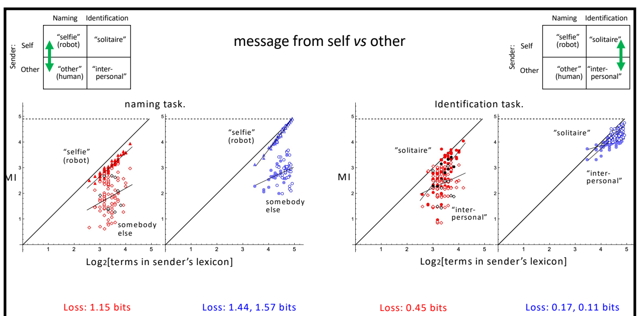

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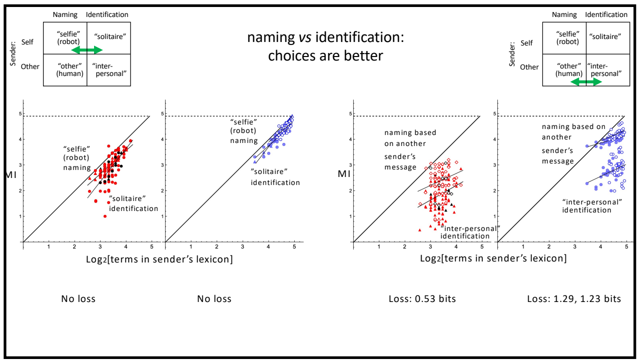

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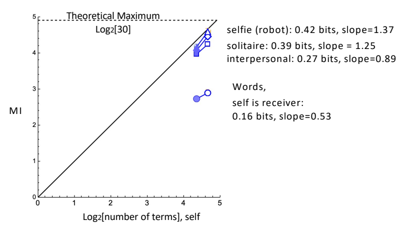
Experience matters.



Experience can cause the number of terms to increase, and the MI increases approximately proportionately.

Again, people don't mostly subdivide the bigger categories until they get close the the theoretical maximum line (where many categories contain one sample).

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Where is information lost?

(Set by the number of terms) — "Best possible" for lexicon MI = Log_2[nTerms]

Loss ~ 0.6 bits

(Set by the distribution of terms) — "Selfie:" Robot is receiver using the sender's dictionary.

No loss!

(Same limits as on the selfie) — "Solitaire:" Human receiver, choosing a sample based on own color messages.

Somali: 0.45 bits, English: no loss

(limited by differences among human lexicons) — "Interpersonal:" Human receiver, choosing based on another person's color messages.

Loss 1.1 – 1.5 bits

(further limited by differences among human lexicons) — Choice succeeds if a sample with the correct color name is chosen

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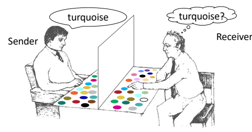
Conclusions

- The Color Communication Game is a useful tool for quantitative analysis of color cognition.
- More color terms → better color communication.
  - People who use more terms do better than those with fewer.
  - Allowing 2 terms produces more terms and better performance.
  - Experience with the task leads to more terms and better performance.
- Performance is better for color selection than for color naming:
  - Color knowledge is better than is revealed by color naming.
- Interpersonal diversity in idiolects adversely affects color communication (people never do as well with other people's messages as they do with their own).
- Culture matters (perhaps related to diversity within the group lexicon).



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Thanks for listening!

Supported by NSF BCS-1152841 and institutional support from the Ohio State Universty's Department of Psychology and the College of Optometry

We thank our many participants, especially members of the Somali community in Columbus Ohio, and our interpreter Mr Abdi Isse, whithout whom this research could never have happened.

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