The background image shows various components of the Cluedoku board game. In the top left, a detective figure in a yellow raincoat stands on a blue circular base. To the right, two more figures, a man in a purple shirt and a woman in a red dress, stand on similar bases. The board features a grid of rooms with red borders, including a kitchen, a living room with a green sofa, and a hallway. A 'CLUE' card is visible in the top right corner. A white semi-transparent box is overlaid on the center of the image, containing the title text. Another white semi-transparent box is overlaid at the bottom, containing the authors' names.

# *Cluedoku: Generating and Solving Clue Logic Puzzles*

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# *History of Clue*

- 🔍 Invented by Anthony E. Pratt in 1944
- 🔍 Originally "Cluedo" = clue + Ludo (Latin for "I play", Europe's Pachisi)
- 🔍 Cluedo production delayed to 1948 by post-war shortages
- 🔍 Most popular deductive game



Collect  
Library  
Study  
**CLUE**

**HALL**

**AGE**

**START  
MISS  
SCARLET**

**MISS SCARLET**

Police evide-  
Case number 001  
CLASSIFIED

**REVOLVER**

Police evide-  
Case number  
CLASSIFIED

**HALL**

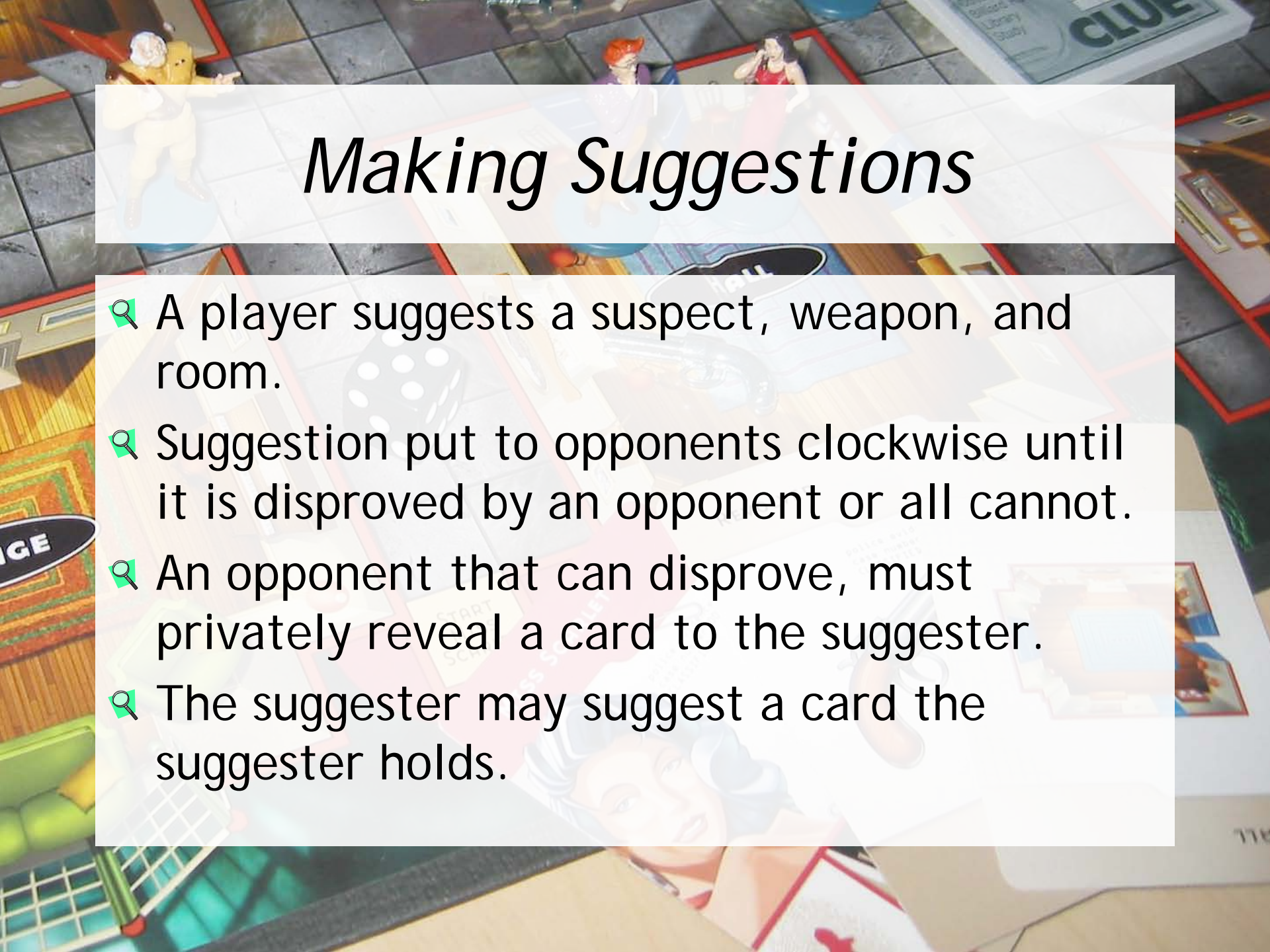


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The background of the slide is a top-down view of a Clue game board. It shows a grid of rooms with various furniture and objects. A white semi-transparent box is overlaid on the top half of the board, containing the title and a list of game rules. The board includes a 'CLUE' box in the top right, a 'HALL' label, and a 'MURDER' label. A woman in a red dress is visible in the top right room, and a man in a white suit is in the top left room. A green sofa is in the bottom left corner.

# *Clue Game Play*

- 🔍 Goal: Deduce correct murder suspect, weapon, and room
- 🔍 21 cards: 6 suspects, 6 weapons, 9 rooms
- 🔍 One card of each type selected randomly, placed unseen in case file
- 🔍 Remaining 18 cards dealt to players (sometimes unevenly)
- 🔍 Players assume suspect identities (irrelevant to play)



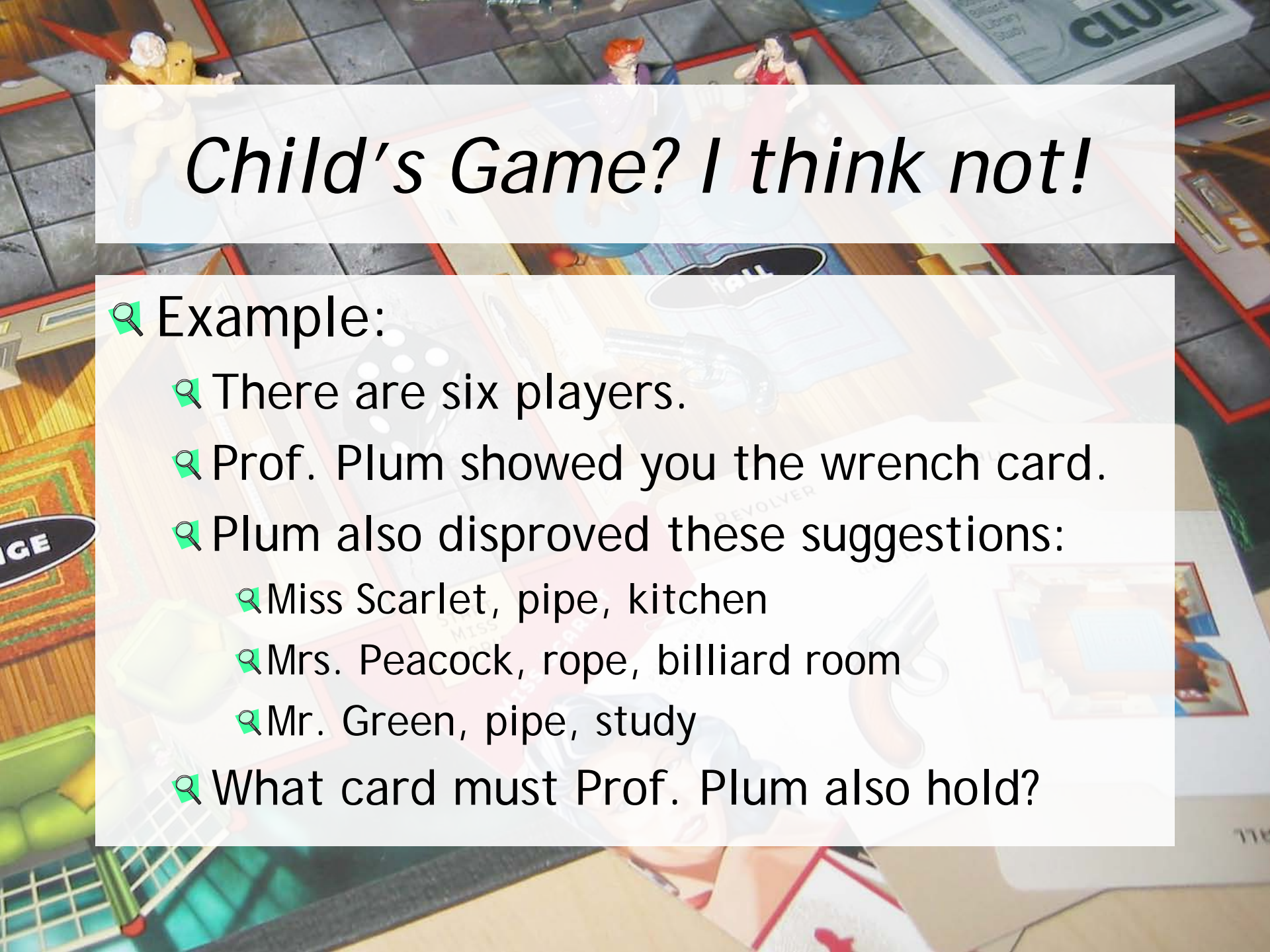
# *Making Suggestions*

- 🔍 A player suggests a suspect, weapon, and room.
- 🔍 Suggestion put to opponents clockwise until it is disproved by an opponent or all cannot.
- 🔍 An opponent that can disprove, must privately reveal a card to the suggester.
- 🔍 The suggester may suggest a card the suggester holds.

The background image shows a top-down view of a board game. In the upper left, a yellow bear-like figure stands on a grey tile. In the center, a woman in a red dress and a man in a purple shirt are visible. A large white card with a woman's face is in the foreground. Other cards and a revolver are scattered on the board. The board has a grid pattern with red and blue lines.

# *Making Accusations*

- 🔍 Each player may declare one accusation in the game, checking the case file for correctness.
  - 🔍 Correct: player wins
  - 🔍 Incorrect: player loses and continues to disprove suggestions.

A background image of a Clue board game. It shows a top-down view of the game board with various rooms like 'Hall', 'Kitchen', 'Billiard Room', and 'Study'. There are several player pieces on the board, including a woman in a red dress (Miss Scarlet) and a man in a purple suit (Mr. Green). A 'CLUE' card is visible in the top right corner. The text 'Child's Game? I think not!' is overlaid in a white box.

# *Child's Game? I think not!*

## 🔍 Example:

- 🔍 There are six players.
- 🔍 Prof. Plum showed you the wrench card.
- 🔍 Plum also disproved these suggestions:
  - 🔍 Miss Scarlet, pipe, kitchen
  - 🔍 Mrs. Peacock, rope, billiard room
  - 🔍 Mr. Green, pipe, study
- 🔍 What card must Prof. Plum also hold?

The background is a top-down view of a Clue board game. It shows a tiled floor with various rooms and corridors. A large white semi-transparent box is overlaid on the top half of the image, containing the title. Another white semi-transparent box is overlaid on the bottom half, containing two bullet points. The board includes a 'START MISS SCARLET' card, a 'MISS SCARLET' card, a 'REVOLVER' card, and a 'HALL' card. A small figure of a woman in a red dress is visible in the top right corner of the board.

# *Creating a ClueReasoner*

- 🔍 Research expanding on an Artificial Intelligence (AI) assignment
- 🔍 How the computer solves deductive logic (search - trial and error)





# *Simulating a Game*

- 🔍 Boardless Clue
- 🔍 Players make suggestions in turn until a player has deduced the solution
- 🔍 Each player is backed by the same reasoning and suggestion-making methods

The background of the slide is a photograph of a Clue board game. It shows a top-down view of the game board with its various rooms like the Hall, Kitchen, and Parlor. Several player pieces are visible, and a Clue card is partially visible in the upper right corner. The text is overlaid on a semi-transparent white box.

# *The Optimal Player*

- 🔍 Each player has the same Clue Reasoner
- 🔍 Suggesting
- 🔍 Accusing
- 🔍 What do we do with a simulated game?

# *What is a Clue Logic puzzle?*

- 🔍 Once the game has finished we look at the game's suggestions from the winner's perspective
- 🔍 Cards dealt + suggestions needed = logic puzzle
- 🔍 How are these made more challenging?

# *Just the (Minimal) Facts, Ma'am*

🔍 Many suggestions aren't necessary, and make redundant paths to solution

🔍 Removing them makes the puzzle more difficult (sometimes)

🔍 So how do we classify easy/medium/hard puzzles?

## MINIMUM SUBSET:

Sugg	Card1	Card2	Card3	Refut	Card5
wh	sc	ca	st	gr	?
gr	pe	kn	ha	sc	?
pe	wh	wr	ba	pl	?
pl	mu	ca	ba	gr	?
wh	wh	pi	di	pl	?
gr	gr	ro	ha	pl	?
pl	gr	re	co	mu	re
sc	wh	pi	bi	wh	?
mu	pl	kn	di	gr	pl
pe	pe	pi	lo	pl	?
pl	pl	pi	bi	sc	?
mu	sc	wr	ha	gr	ha
gr	mu	re	ha	mu	re
sc	pe	ro	co	pl	?

The background of the slide is a top-down view of a board game. It features a grid of square tiles in shades of grey and brown. Several miniature figures are placed on the board, including a woman in a white dress and a man in a red suit. There are also various cards and objects scattered around, such as a 'CLUE' card, a 'MISS SCARLET' card, and a revolver. The overall scene is a detailed and colorful representation of a classic board game.

# *Rating the Puzzles*

- 🔍 Modeling through introspection
  - 🔍 Do a lot of puzzles
  - 🔍 Observe rules of inference we use
  - 🔍 Model human-style reasoning in software
- 🔍 Degrees of logic

The background of the slide is a top-down view of a Clue board game. It shows a tiled floor with various rooms and corridors. A large white semi-transparent box is overlaid on the top half of the board. In the bottom right corner, a smaller white semi-transparent box is overlaid on a card that features a revolver and a woman's face. The card text includes 'MISS SCARLETT', 'REVOLVER', and 'HALL'.

# *Basic Clue Reasoning*

- 🔍 Basic Reasoning
  - 🔍 Card location
  - 🔍 Case file contents
  - 🔍 Number of cards dealt
  - 🔍 Cards secretly shown

The background image shows a board game board with a grid of squares. Several miniature figures are placed on the board. A large card with a woman's face and the text 'MISS SCARLET' is prominent. Other cards and items like 'REVOLVER' and 'CLUE' are visible. A semi-transparent white box is overlaid on the board, containing the title and two bullet points.

# *Card Location*

- 🔍 If you know where a card is, you know where it is not.
- 🔍 If you know where a card is not, you know where it is.

The background image shows a top-down view of a board game board. It features a grid of squares, some of which are colored in shades of blue, green, and red. There are several small figures or pieces on the board, including one in a yellow outfit and another in a red dress. A large card with the word "CLUE" is visible in the upper right corner. The overall scene is brightly lit and colorful.

# *Case File Contents*

- 🔍 Exactly one card of each category is in the case file.
- 🔍 If you know a card is in the case file, no other cards in that category are in the case file.
- 🔍 If you know all cards of a category but one are not in the case file, then that one is in the case file.



The background of the slide is a top-down view of a Clue board game. It shows a tiled floor with various rooms and furniture. In the top left, there is a yellow chair and a red table. In the center, there are several miniature figures of people. In the bottom right, there is a large illustration of a woman's face, likely Mrs. Peacock. A 'CLUE' card is visible in the top right corner. The text is overlaid on a semi-transparent white box.

# *Number of Cards Dealt*

- 🔍 Note how many cards each player was dealt.
- 🔍 If you know all cards a player has, the player has no other cards.
- 🔍 If you know all cards a player does not have, the player has all other cards.

# *Cards Secretly Shown*

- 🔍 Note disproved suggestions where you do not see the card shown.
- 🔍 If a player does not have two of the cards possibly shown, the player must have the third.

**Winner:** pe

**Cards:** ro wh co

Suggestor	Suggestion			Disproof	
	Suspect	Weapon	Room	By	W/ Card
sc	pl	re	lo	gr	?
mu	sc	ca	di	wh	?
wh	mu	wr	co	pe	co
gr	pe	ca	li	pl	?
pl	pl	kn	lo	mu	?
mu	wh	wr	st	pe	wh
pe	pe	wr	ki	mu	ki
pl	gr	wr	ki	mu	?
mu	pe	ca	ha	gr	?
gr	pe	pi	ki	pl	?
pe	wh	ro	di	pl	di
pl	gr	ca	ha	sc	?
sc	sc	wr	li	mu	?
mu	pl	kn	ki	?	?
wh	gr	re	ba	sc	?
gr	pl	ca	ba	wh	?

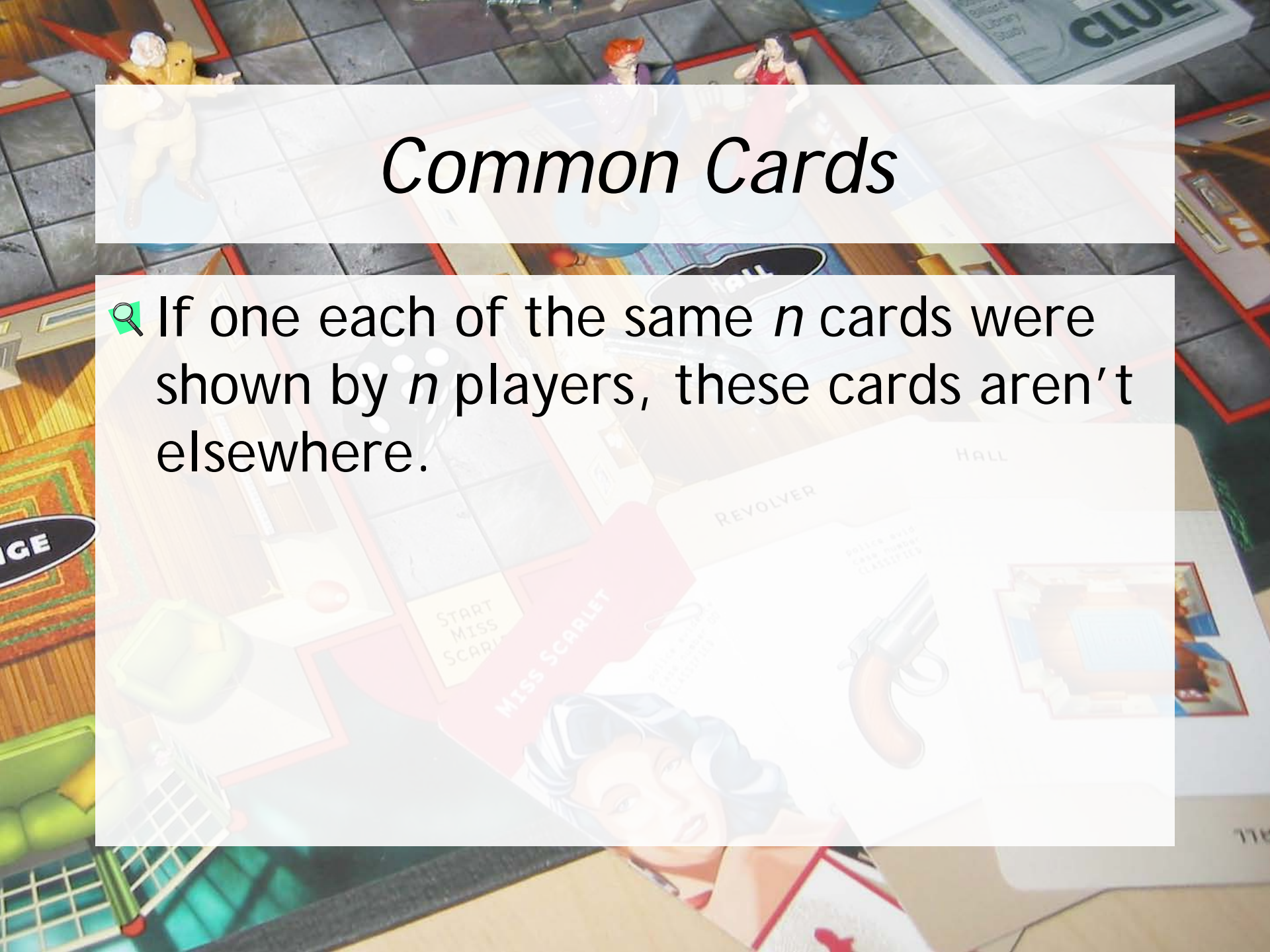
	Sc	Mu	Wh	Gr	Pe	Pl	CF
Mustard	<b>Mu</b>			X	X	X	
Plum	<b>Pl</b>	X	X	X	X	X	
Green	<b>Gr</b>	X			X	X	
Peacock	<b>Pe</b>	X		X		X	
Scarlet	<b>Sc</b>				X		
White	<b>Wh</b>			X	X	○	
Knife	<b>Kn</b>	X		X	X	X	
Candlestick	<b>Ca</b>	X	X	X		X	
Revolver	<b>Re</b>		X	X	X	X	
Rope	<b>Ro</b>					○	
Lead Pipe	<b>Pi</b>				X		
Wrench	<b>Wr</b>	X		X	X	X	
Hall	<b>Ha</b>			X		X	
Lounge	<b>Lo</b>	X	X	X		X	
Dining Room	<b>Di</b>					X	○
Kitchen	<b>Ki</b>	X	○	X	X	X	
Ballroom	<b>Ba</b>	X	X		X	X	
Conservatory	<b>Co</b>				X	○	
Billiard room	<b>Bi</b>				X		
Library	<b>Li</b>				X		
Study	<b>St</b>			X	X	X	

**Cards Possibly Shown**

	S	W	R
gr	pt	re	lo
wh	sc	ca	di
pl	pe	ca	li
mu	pt	kn	te
gr	pe	ca	ha
pl	pe	pi	ki
sc	gr	ca	ha
mu	sc	wr	li
sc	gr	re	ba
wh	pt	ca	ba

# Common Cards

🔍 If one each of the same  $n$  cards were shown by  $n$  players, these cards aren't elsewhere.





# *Example*

- 🔍 Plum showed the pipe or the hall.
- 🔍 Green showed the pipe or the hall.
- 🔍 The pipe and the hall cards cannot be elsewhere (e.g. in the case file).

# *Disjoint Unknown Refutations*

## 🔍 Suppose

- 🔍 We don't know  $n$  of a player's cards.
- 🔍 We don't know which card was shown in  $n$  disjoint refutations (no possible cards in common)

## 🔍 Then

- 🔍 One of the player's  $n$  unknown cards is in each refutation, so...
- 🔍 *No cards beyond these possibilities can be in the player's hand.*



# *Example*

- 🔍 We don't know 2 of Prof. Plums cards.
- 🔍 We know that
  - 🔍 (1) Plum has 3 cards, one of these being the knife.
  - 🔍 (2) Plum showed White, pipe, or hall
  - 🔍 (3) Plum showed Green, rope, or study
- 🔍 Plum's 2 unknown cards must account for (2) and (3).
- 🔍 Plum cannot hold cards beyond these.

The background is a detailed image of a board game board, likely a murder mystery game. It features a grid of rooms and corridors. Several cards are visible, including one labeled 'CLUE' and another with 'MISS SCARLET' and 'REVOLVER'. There are also small figurines of characters on the board. The overall scene is brightly lit and colorful.

# *Accounting for Refutations*

- 🔍 Further, we can hypothesize that a player does not have a given card.
- 🔍 If we then cannot account for all the player's refutations, the player must have that card.
- 🔍 (We can similarly hypothesize that a player has a card.)





# *Example*

- 🔍 Plum has 1 unknown card.
- 🔍 Plum showed White, pipe, or hall
- 🔍 Plum showed Green, pipe, or study
- 🔍 Suppose Plum doesn't have the pipe.
- 🔍 We can't have 1 card cover the remaining possibilities.
- 🔍 Therefore Plum must have the pipe.

A background image of a Clue board. It shows a grid of rooms with names like 'CLUE', 'HALL', 'STUDY', 'ROPE', 'GREEN', 'WHITE', 'PIPE', 'PLUM', 'MURDER', 'MISS CARP', 'REVOLVER', 'SMITH', 'GREEN', 'HALL', 'STUDY', 'ROPE', 'GREEN', 'WHITE', 'PIPE', 'PLUM', 'MURDER', 'MISS CARP', 'REVOLVER', 'SMITH'. There are also small figures of characters on the board.

# *Example*

- 🔍 Plum has 2 unknown cards.
- 🔍 Plum showed White, pipe, or hall
- 🔍 Plum showed Green, rope, or study
- 🔍 Plum showed Plum, rope, or study
- 🔍 Suppose 1 of Plum's unknown cards is Green.
- 🔍 We can't have the 1 remaining card cover the remaining possibilities.
- 🔍 Therefore Plum cannot have Green.

The background of the slide is a top-down view of a Clue board game. It shows a tiled floor with various rooms and corridors. In the top left, a yellow dog is on a red carpet. In the center, a woman in a red dress is talking on a mobile phone. In the bottom center, a woman's face is visible, looking towards the camera. A green magnifying glass is in the bottom left corner. A white card with the word 'CLUE' is in the top right corner. A white card with the word 'HALL' is in the middle right. A white card with the words 'START MISS SCARLETT' is in the middle left. A white card with the words 'SCARLETT' and 'REYON' is in the middle. A white card with the words 'START MISS SCARLETT' is in the middle left. A white card with the words 'SCARLETT' and 'REYON' is in the middle. A white card with the words 'START MISS SCARLETT' is in the middle left. A white card with the words 'SCARLETT' and 'REYON' is in the middle.

# *Conclusion*

- 🔍 Clue can have interesting logic.
- 🔍 Consider the popular deductive puzzle Sudoku
  - 🔍 Invented by Howard Garns, 1979
  - 🔍 Modern popularity due to Wayne Gould who developed his Sudoku generation software over 6 years.
- 🔍 Congratulations to Monica for generating and rating the first Cluedoku puzzles in less than 10 weeks!