Embedded Software

Thread synchronization

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Agenda

- Mutexes/Semaphores
  - Pitfalls
  - Priority Inversion
    - Problem
    - Solution
      - Inversion
      - Inheritance
      - Ceiling
  - Deadlocks

Mutex & Semaphore pitfalls

Mutexes & Semaphores: Pitfalls

- It is extremely easy to get in trouble with mutexes!
- ***Example 1: Find and explain the problem***

```
unsigned int shared;
Mutex m = MUTEX_INITIALIZER;

threadFunc()
{
   while(true)
   {
        lock(m);
        shared++;
        sleep(ONE_SECOND);
        unlock(m);
   }
}


main()
{
   shared = 0;
   createThread(threadFunc);
   createThread(threadFunc);
   for(;;) sleep(100);
}
```

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main()
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   for(;;) sleep(100);
}
```

m is held for a **full second**, ***blocking*** the other thread

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unsigned int shared;
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threadFunc()
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   lock(m);
   while(true)
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You're in a world of pain!

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Mutexes & Semaphores: Pitfalls

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- ***Example 3: Find and explain the problem***

```
unsigned int shared;
SEM_ID s;

threadFunc()
{
   while(true)
   {
        take(s);
        shared++;
        release(s);
        sleep(ONE_SECOND);
   }
}

main()
{
   shared = 0;
   s = createSem(0);
   createThread(threadFunc);
   createThread(threadFunc);
   for(;;) sleep(100);
}
```

Mutexes & Semaphores: Pitfalls

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- ***Example 3: Find and explain the problem***

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unsigned int shared;
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threadFunc()
{
   while(true)
   {
        take(s);
        shared++;
        release(s);
        sleep(ONE_SECOND);
   }
}

main()
{
   shared = 0;
   s = createSem(0);
   createThread(threadFunc);
   createThread(threadFunc);
   for(;;) sleep(100);
}
```
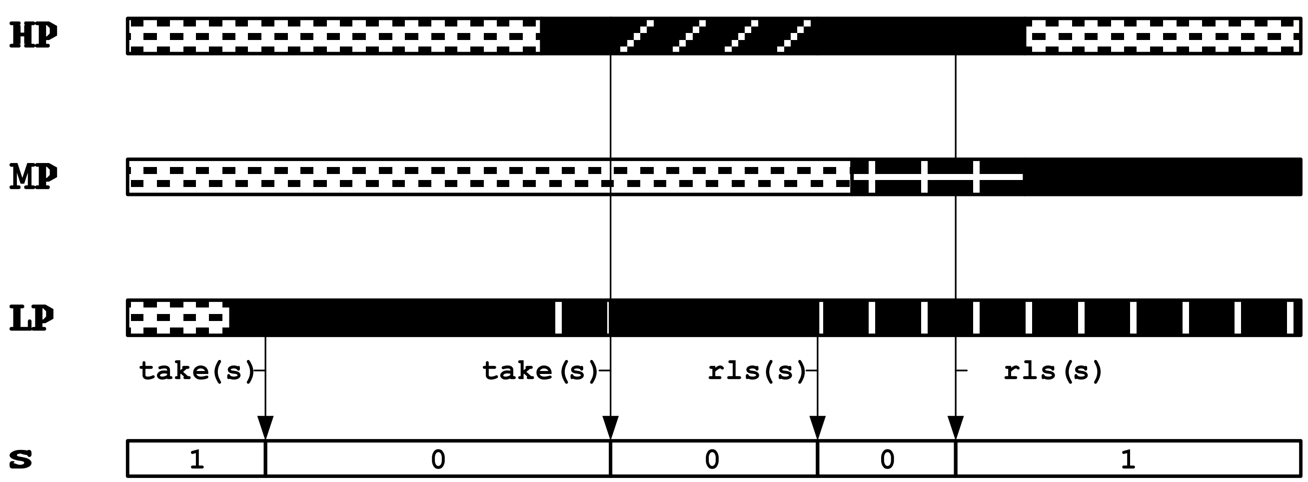
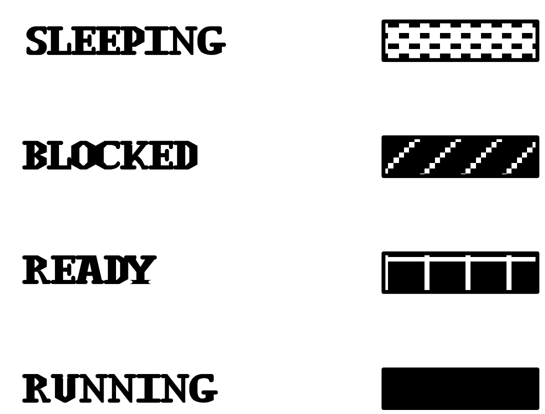

s is initialized to 0 – no one can pass **take()** before someone calls **release()**

Mutex priority

Mutexes & Semaphores: Pitfalls

- Scenario 1:





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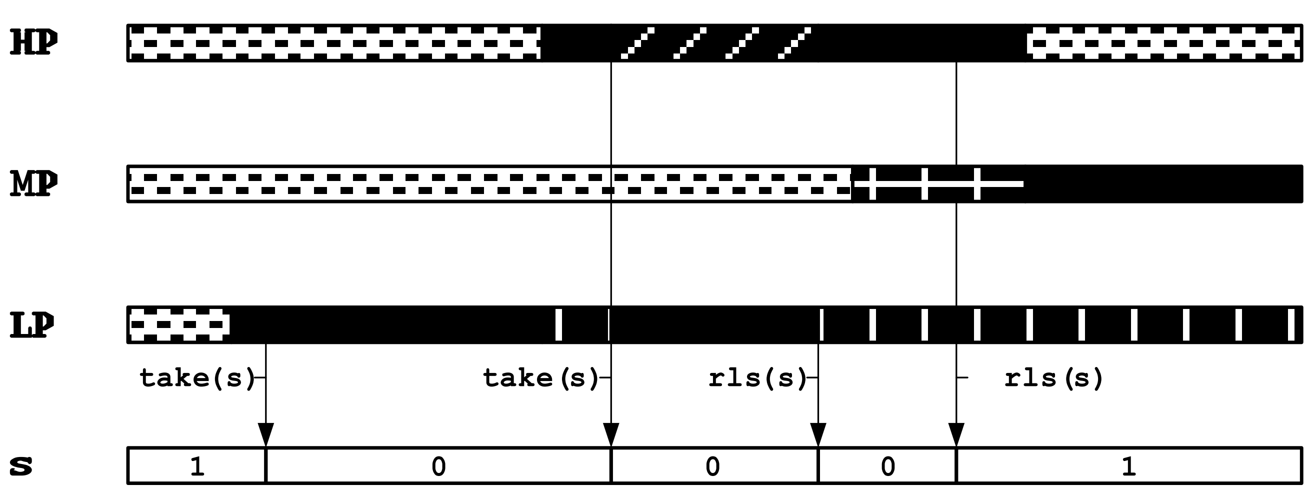

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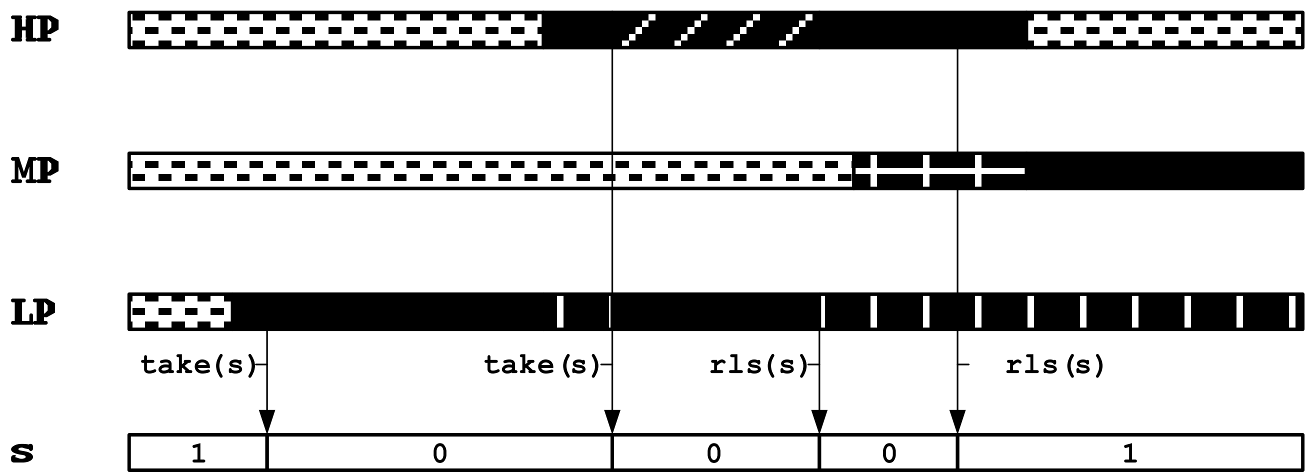

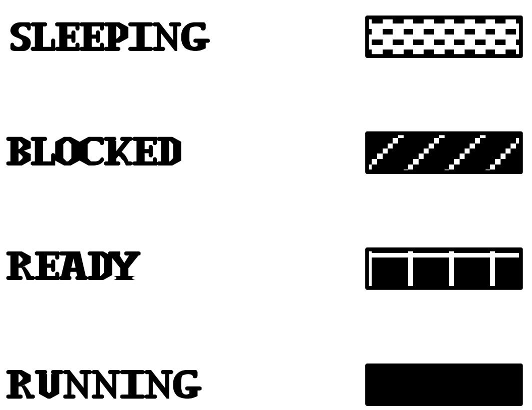

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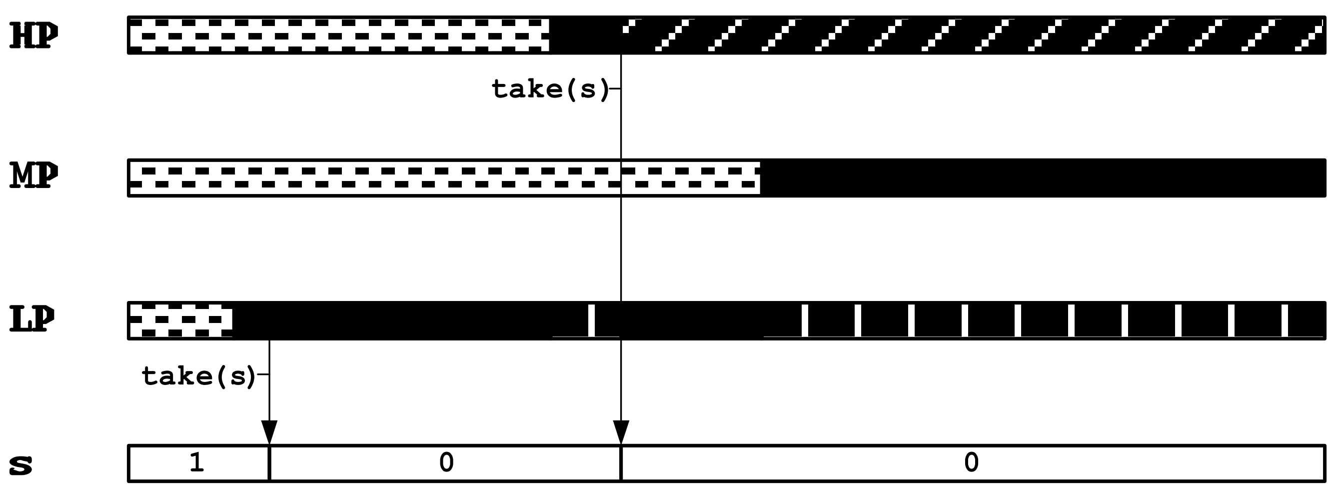

Monday, March 12, 12

Priority inversion

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- Priority inversion is a nasty error – especially in RT systems
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  - “Slower”…”sometimes”…not words the RT system engineer likes!!!

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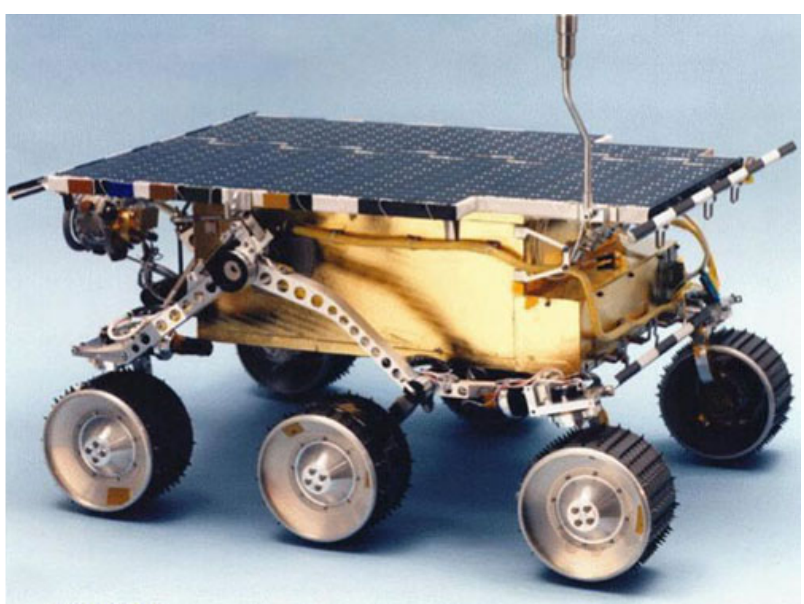

Mars Pathfinder
<u>Problem</u>: Ground communications terminated abruptly ($$$!)
<u>Cause</u>: HW/SW reset by watchdog
<u>Cause</u>: HP data distribution (DD) task not completed on time
<u>Cause</u>: DD-task waited for mutex held by LP ASI/MET task, which was preempted by several MP tasks

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- Note semaphores do ***NOT*** support the above

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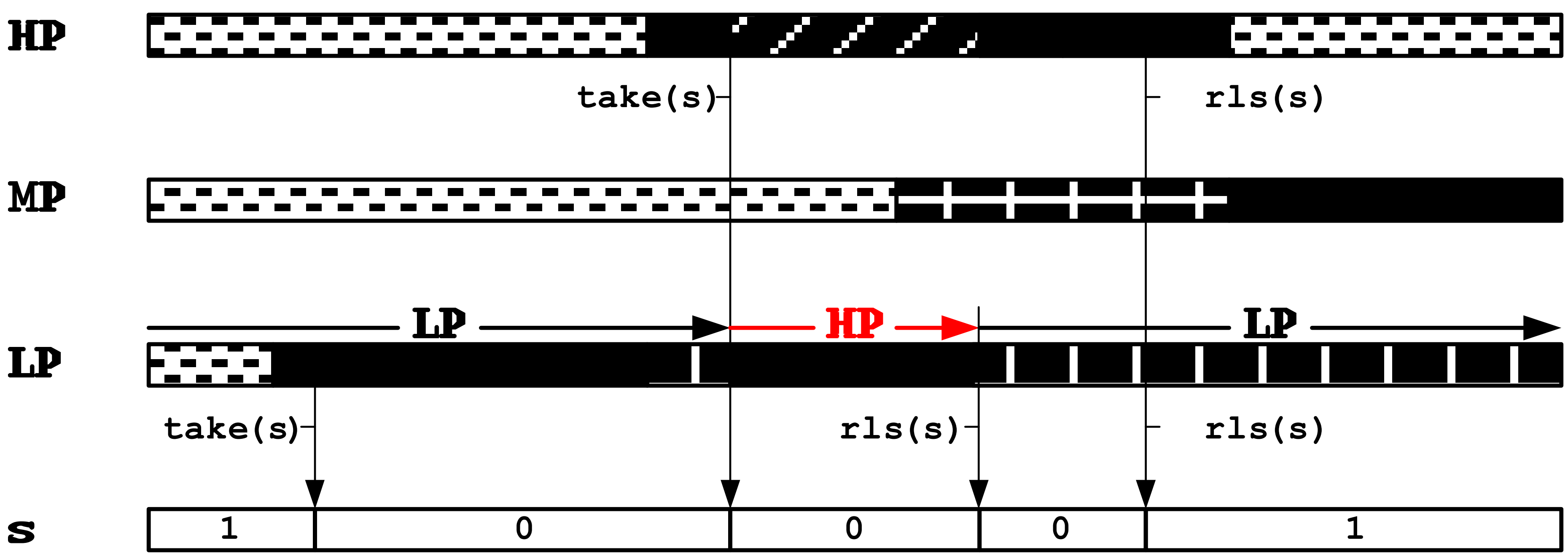

- Priority inheritance can be set as a property of some mutexs on creation

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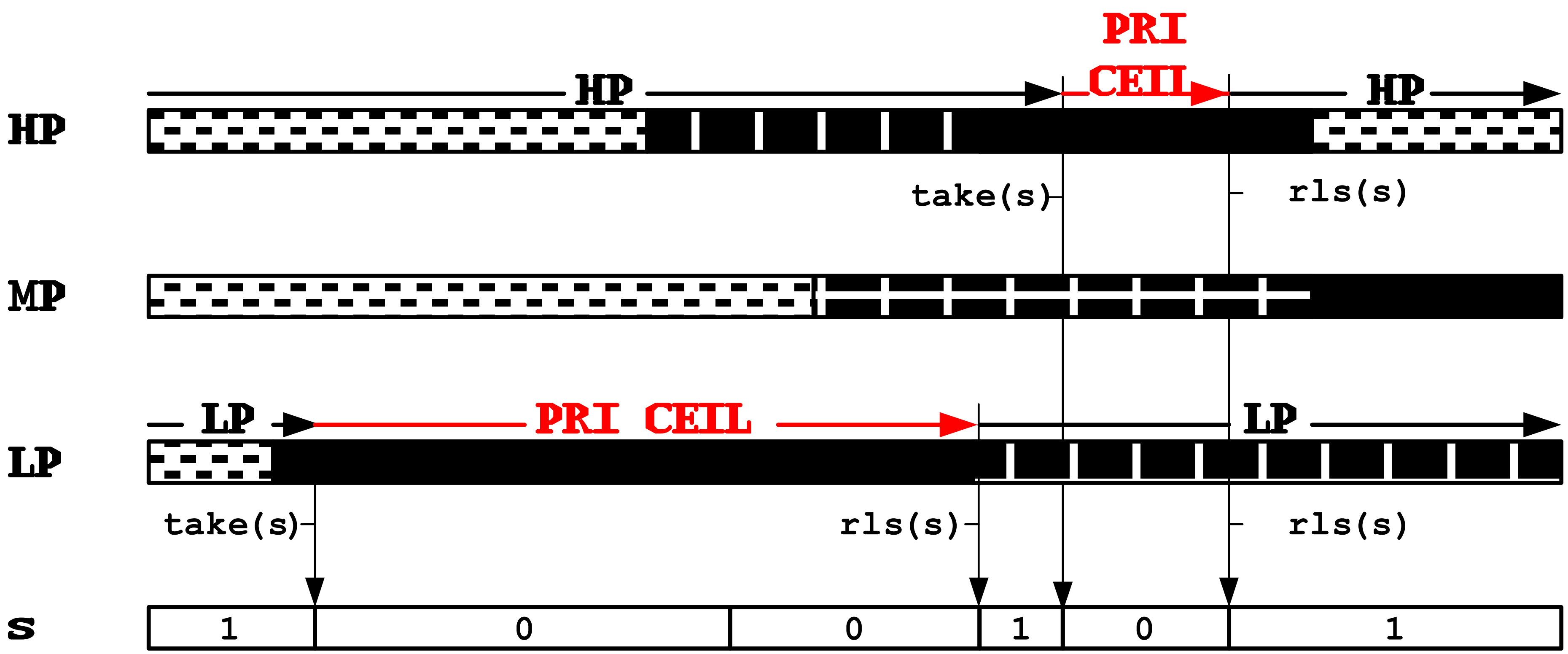

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Multiple Mutexes

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   createThread(printFileFunc1);
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void printFileFunc1()
{
   lock(fileMut);
   lock(printerMut);
   <<print file>>
   unlock(printerMut);
   unlock(fileMut);
}
```

```
void printFileFunc2()
{
   lock(printerMut);
   lock(fileMut);
   <<print file>>
   unlock(fileMut);
   unlock(printerMut);
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void main()
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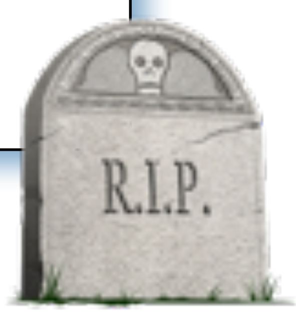


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Deadlocks

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- A deadlock is a situation where two (or more) threads are waiting for the other to release a resource, thus neither will ever run.

- The four necessary conditions for deadlocks:

1. *Mutual exclusion* The resource can only be held by one process at a time
2. *Hold-and-wait* Process already holding resources may request other resources
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> *”When two trains approach each other at a crossing, both shall come to a full stop and neither shall start up again until the other has gone.”* (Kansas Legislation)

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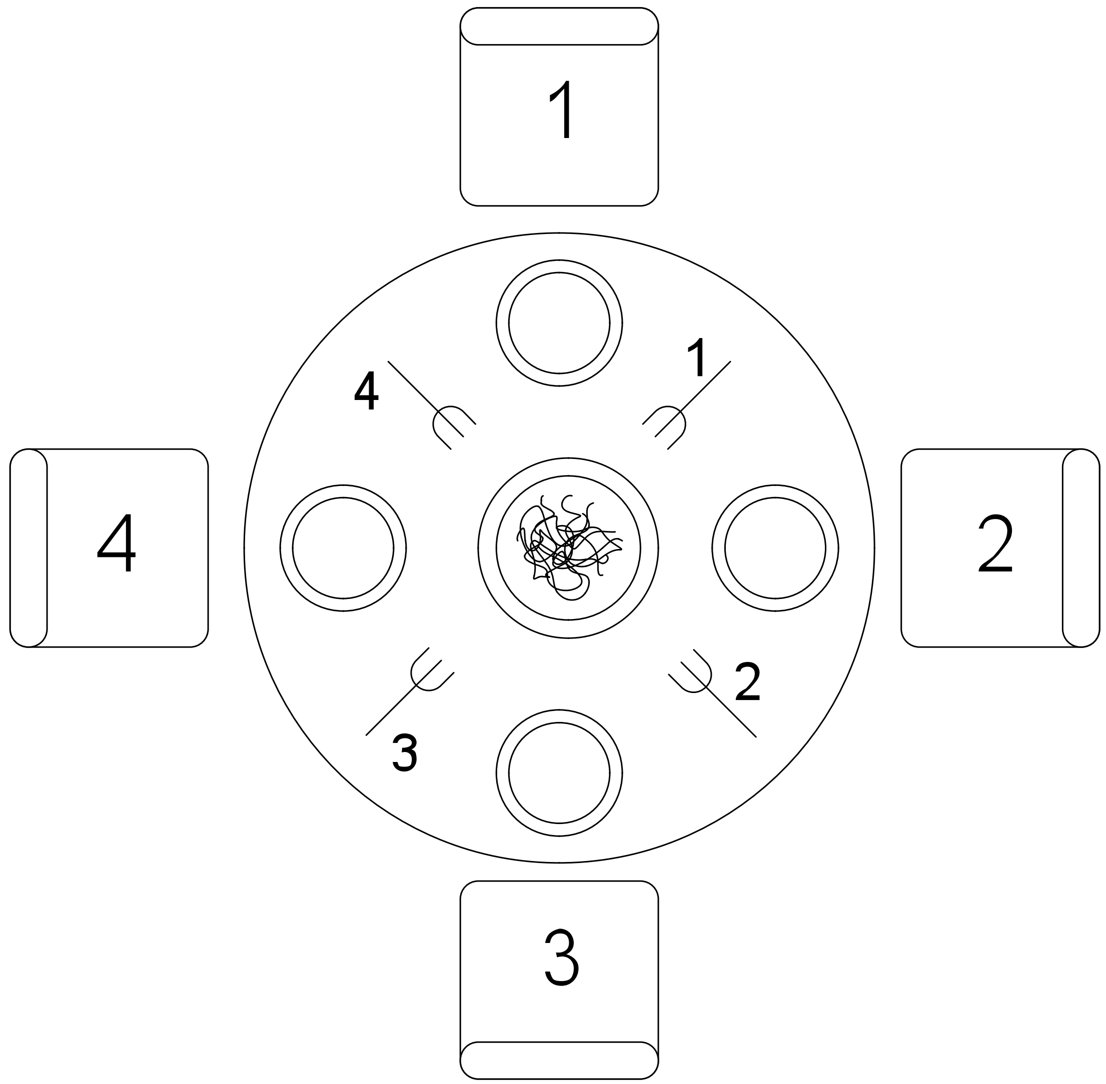
Deadlocks: Dining Philosophers



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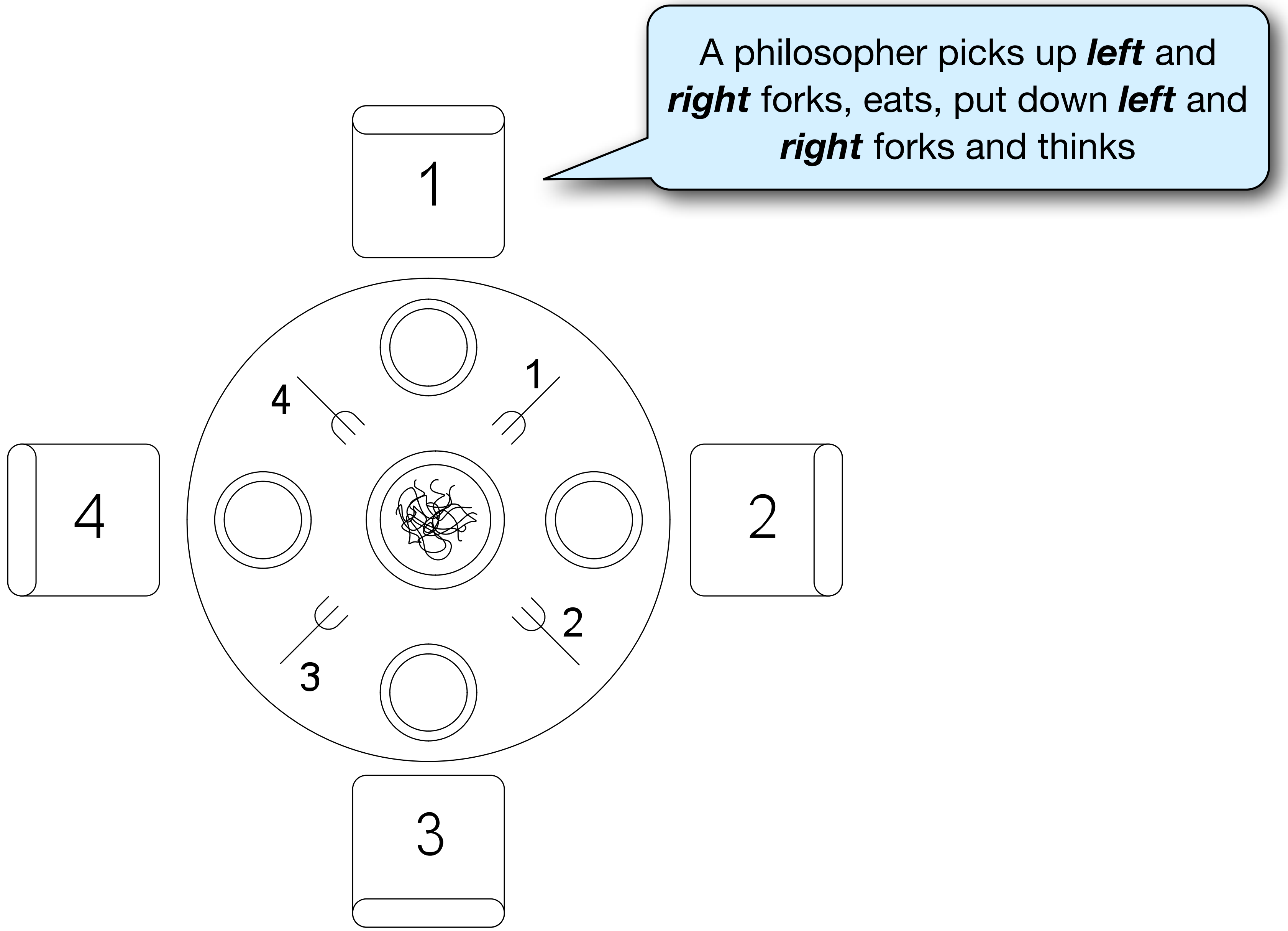

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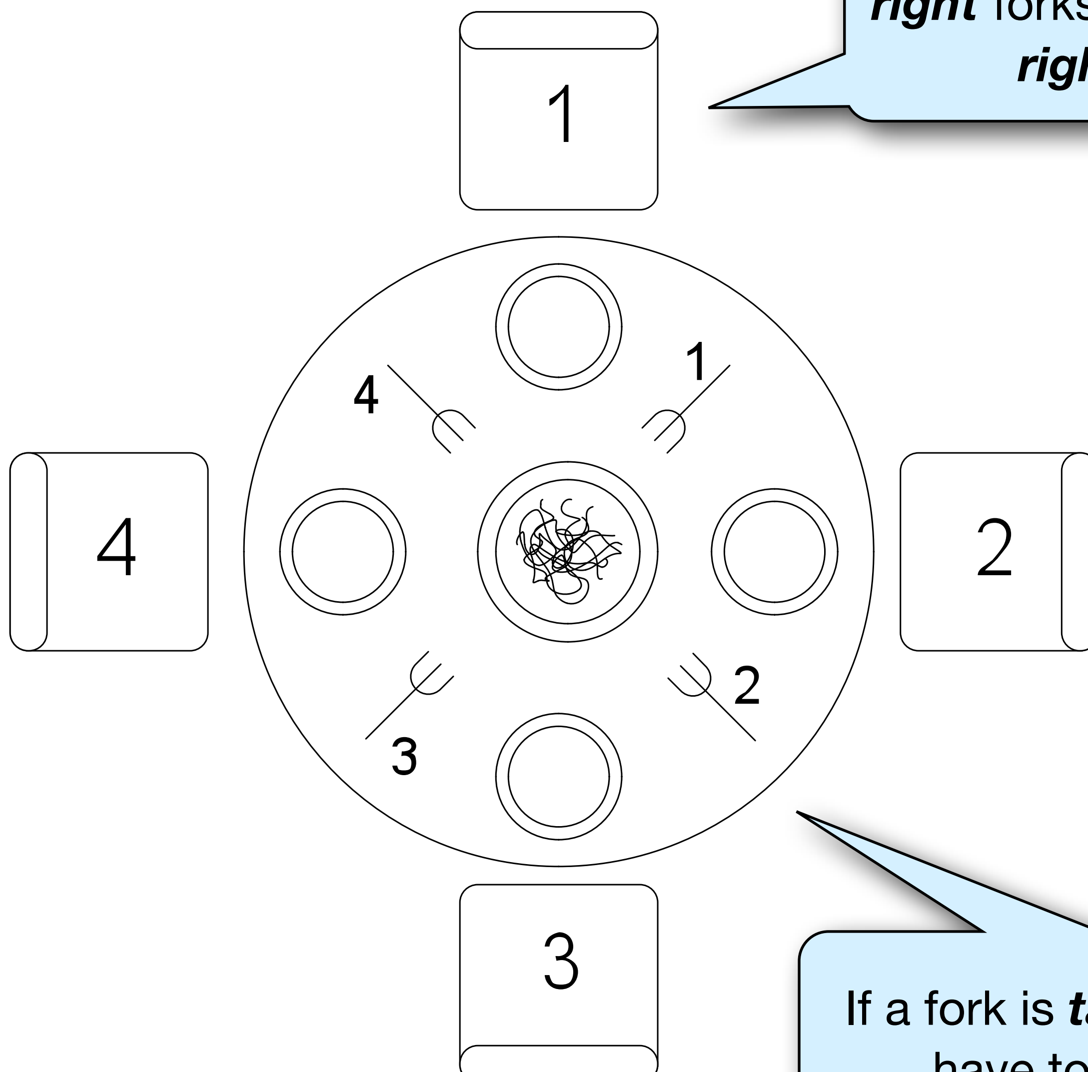

A philosopher picks up ***left*** and ***right*** forks, eats, put down ***left*** and ***right*** forks and thinks

If a fork is ***taken*** the philosopher will have to ***wait*** for it to be ***free***

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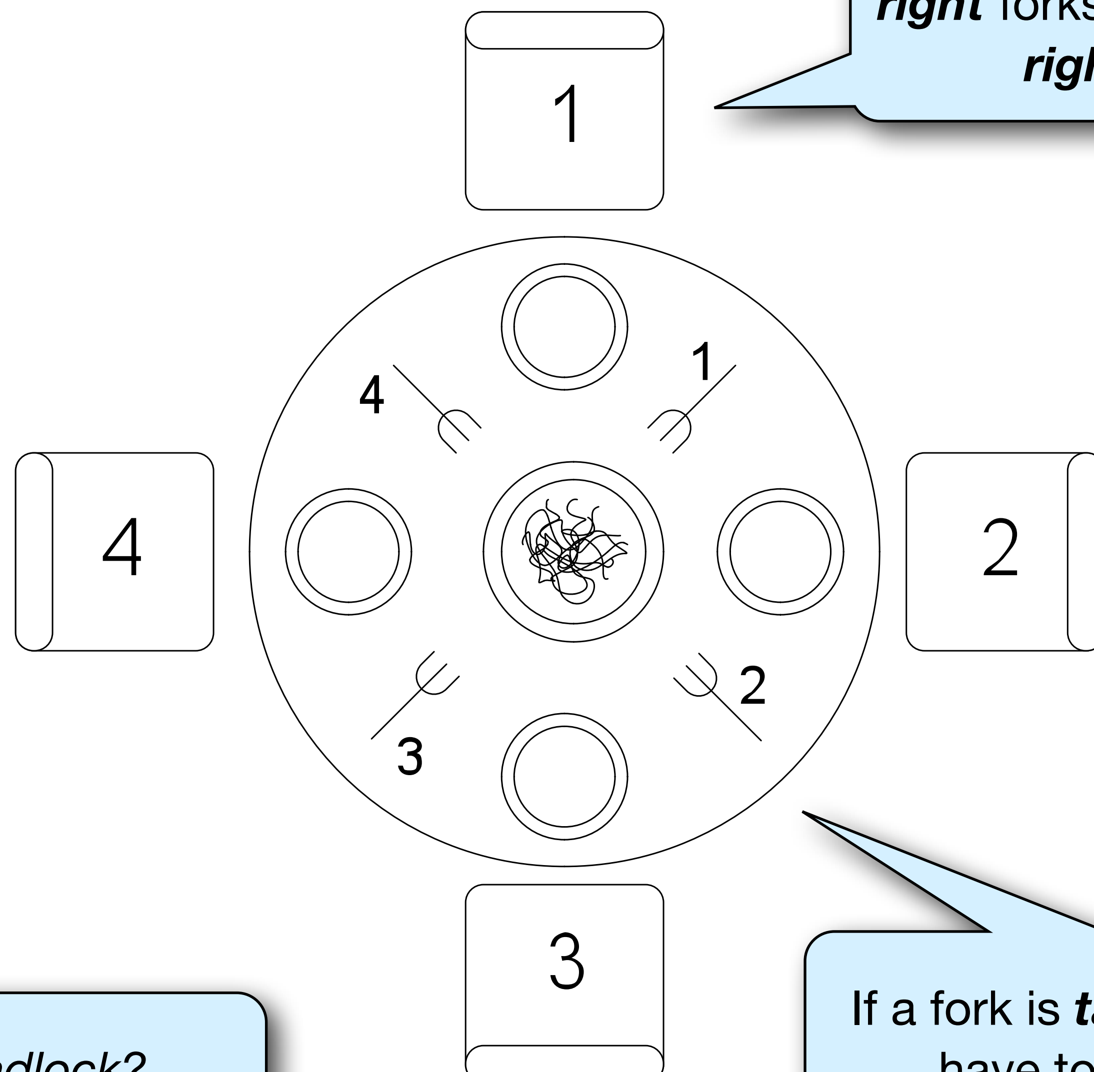

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Can this system deadlock? How?

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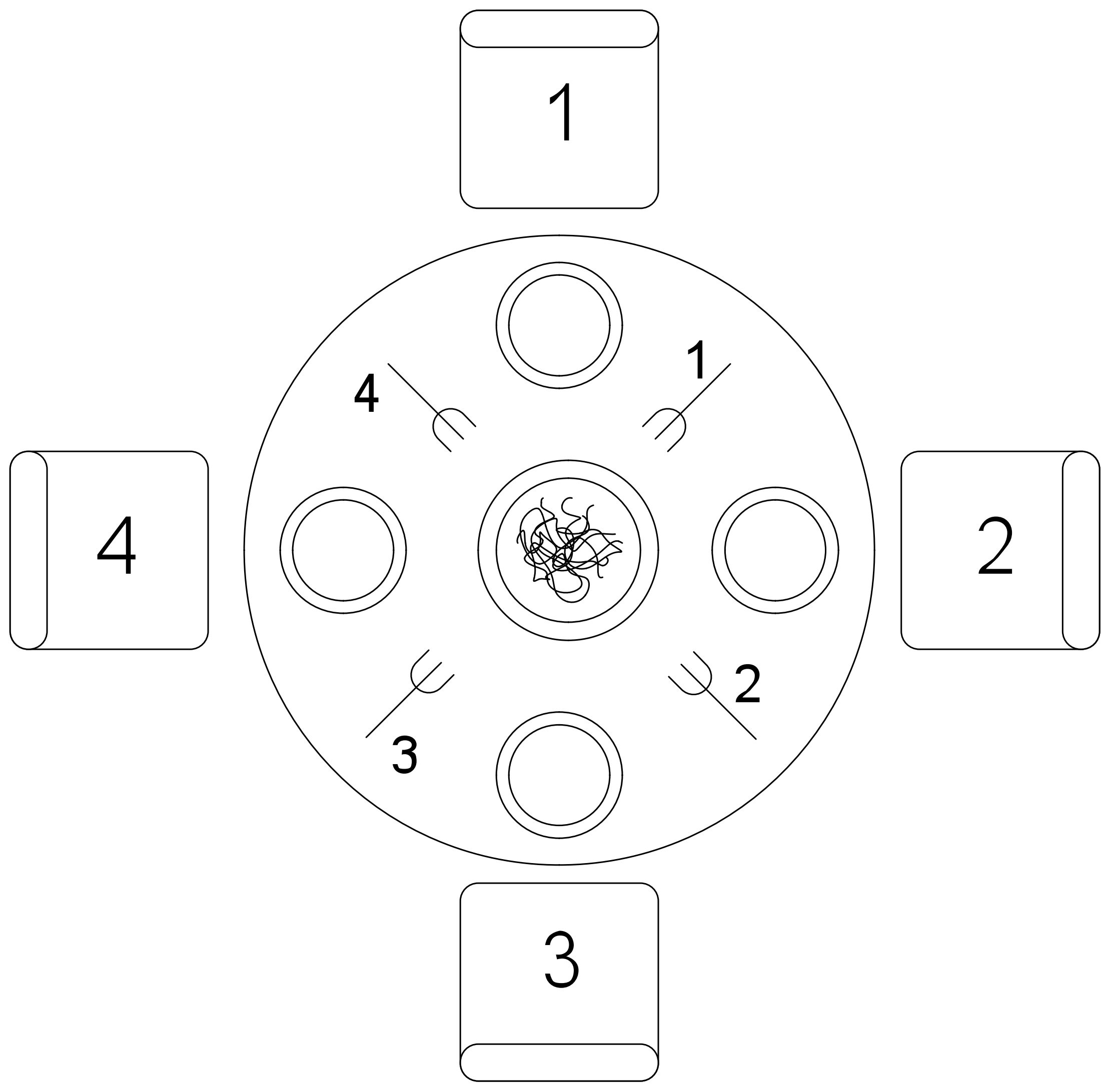

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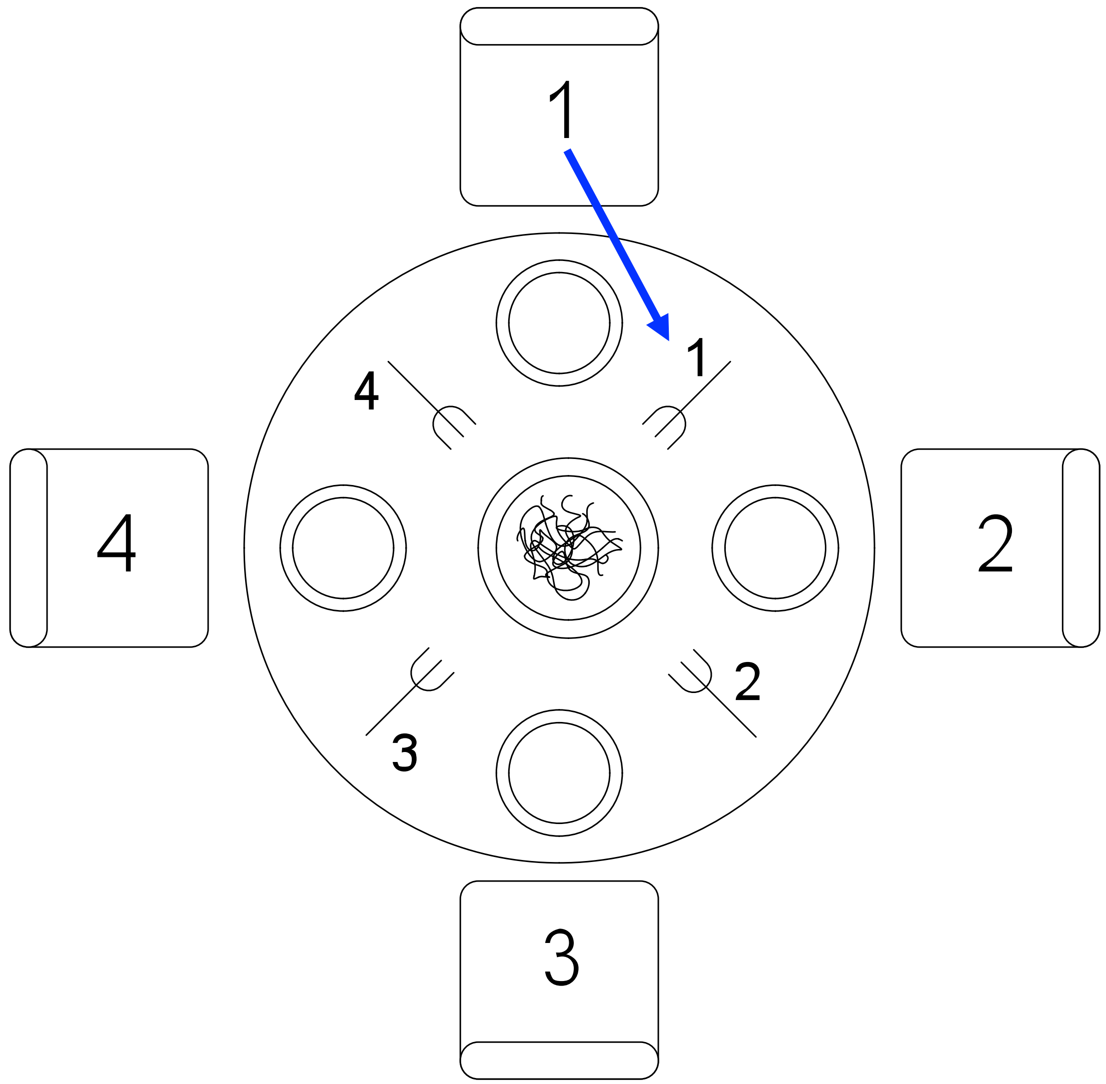

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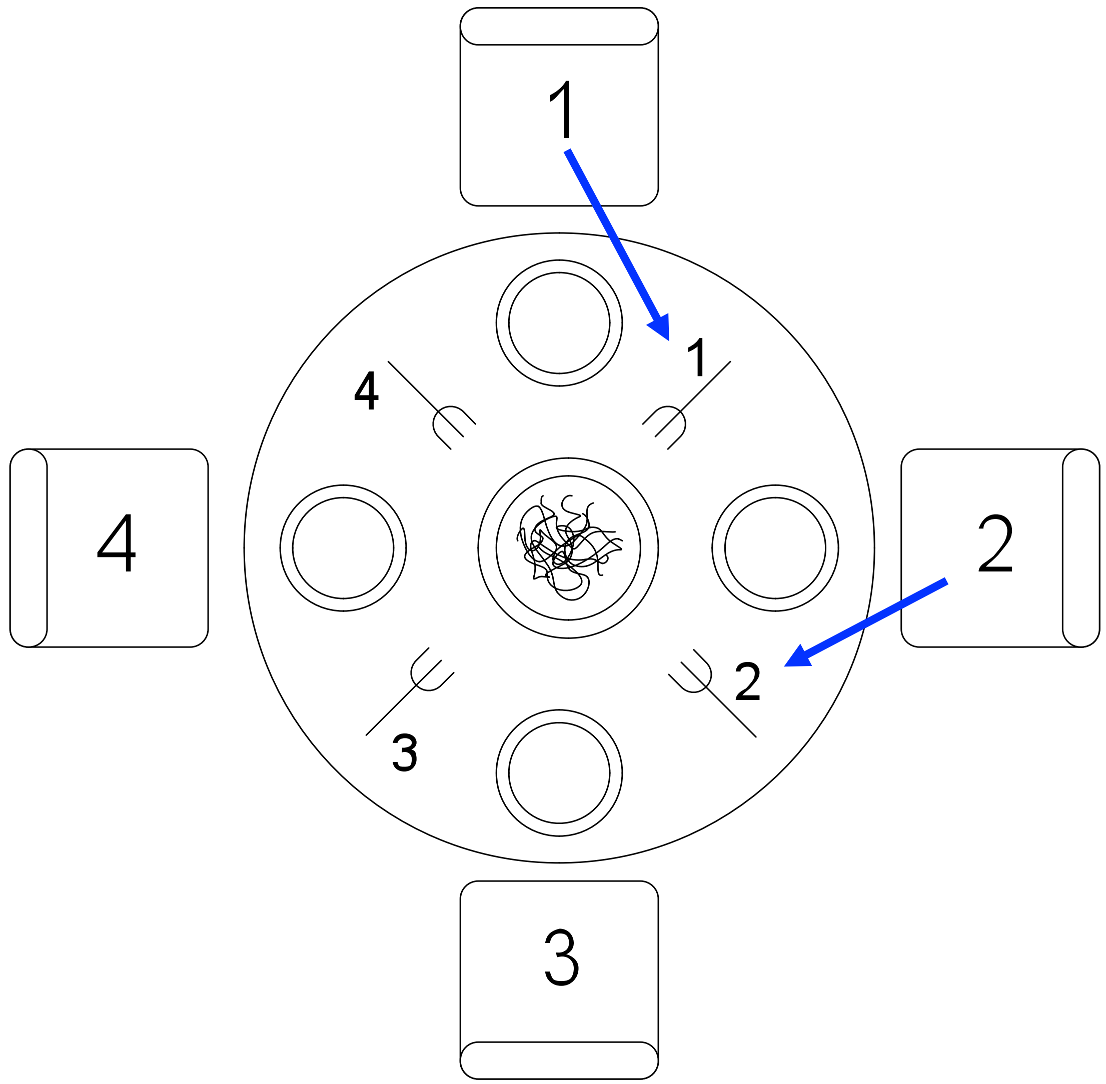

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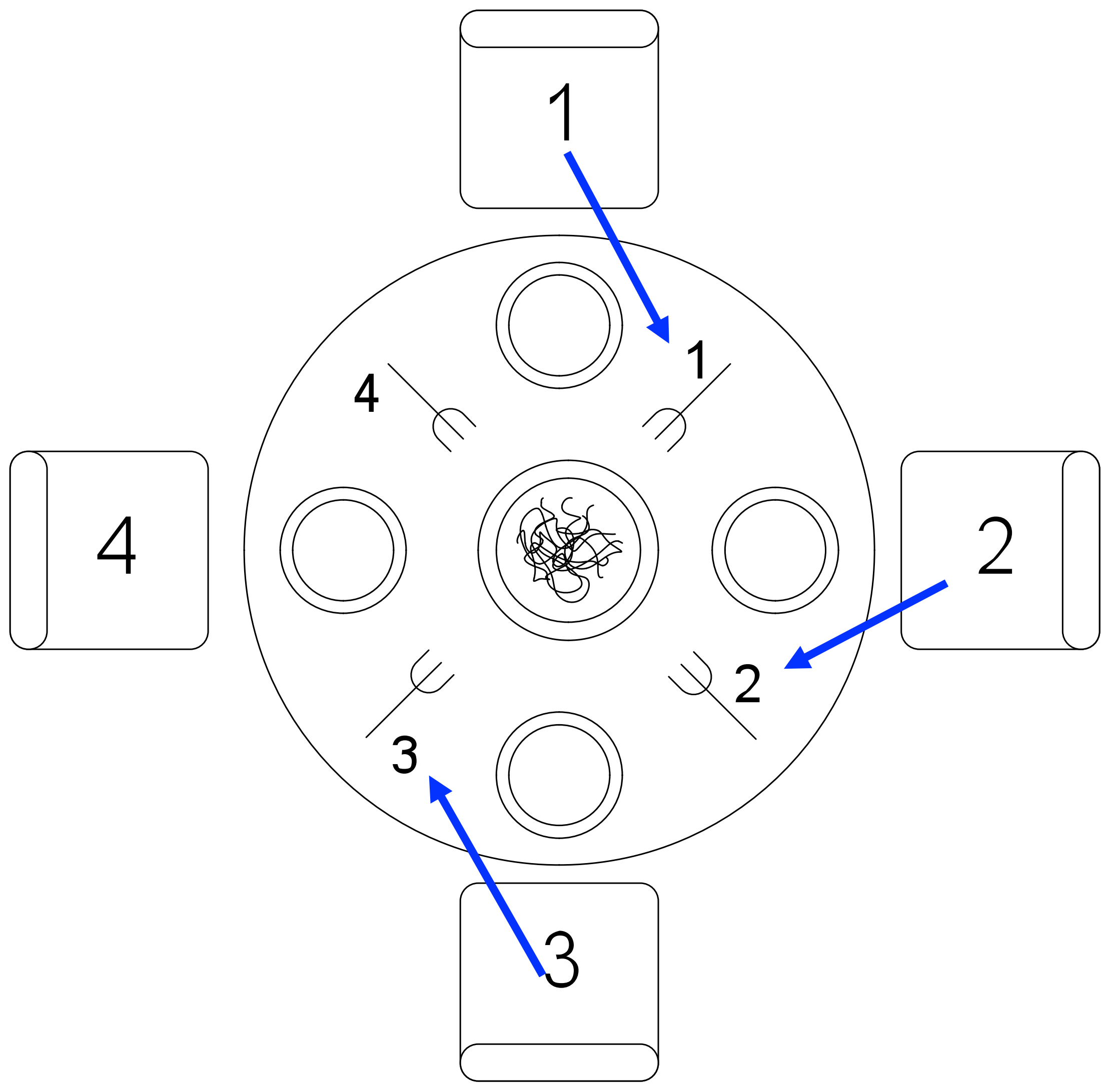

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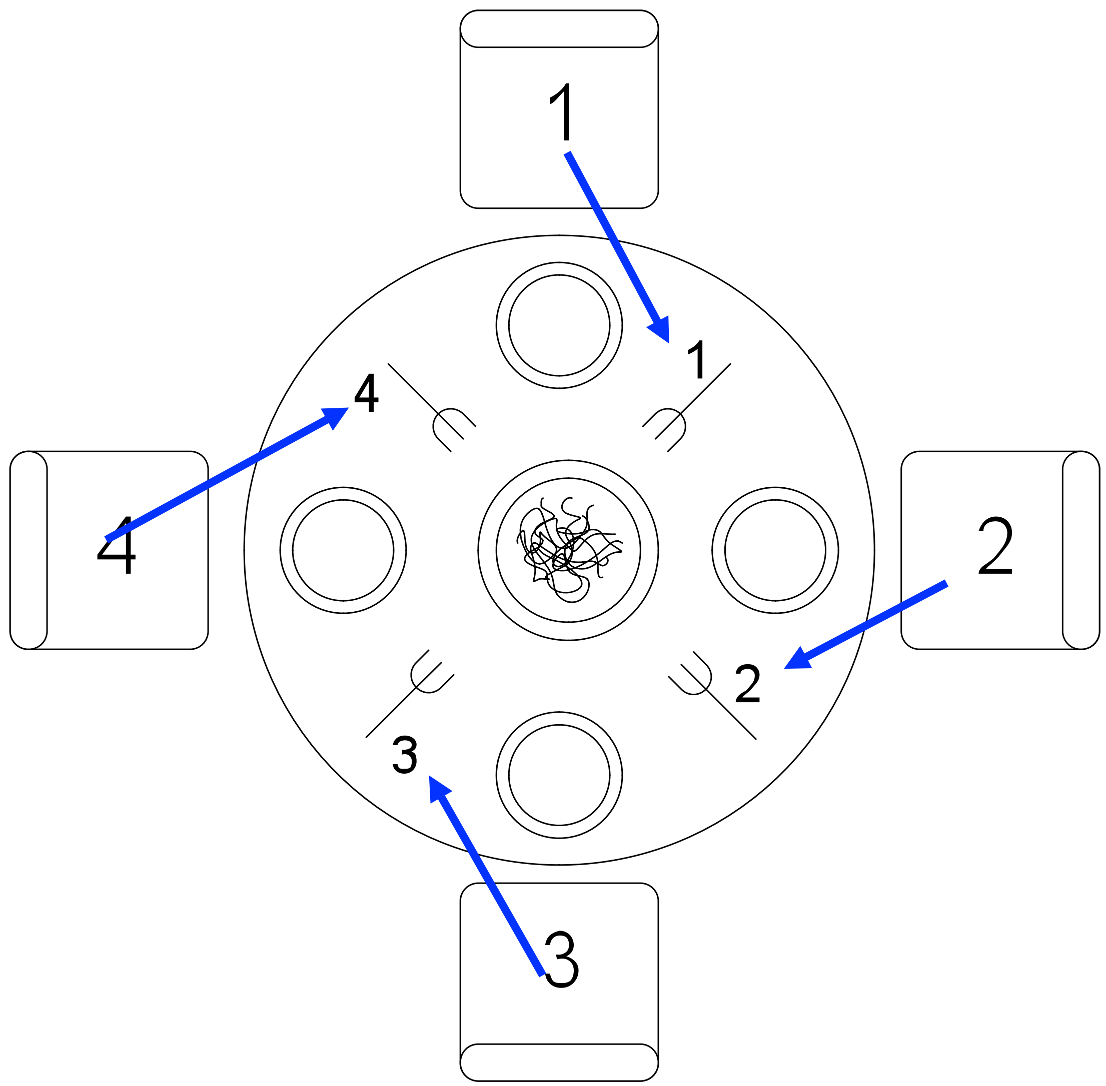

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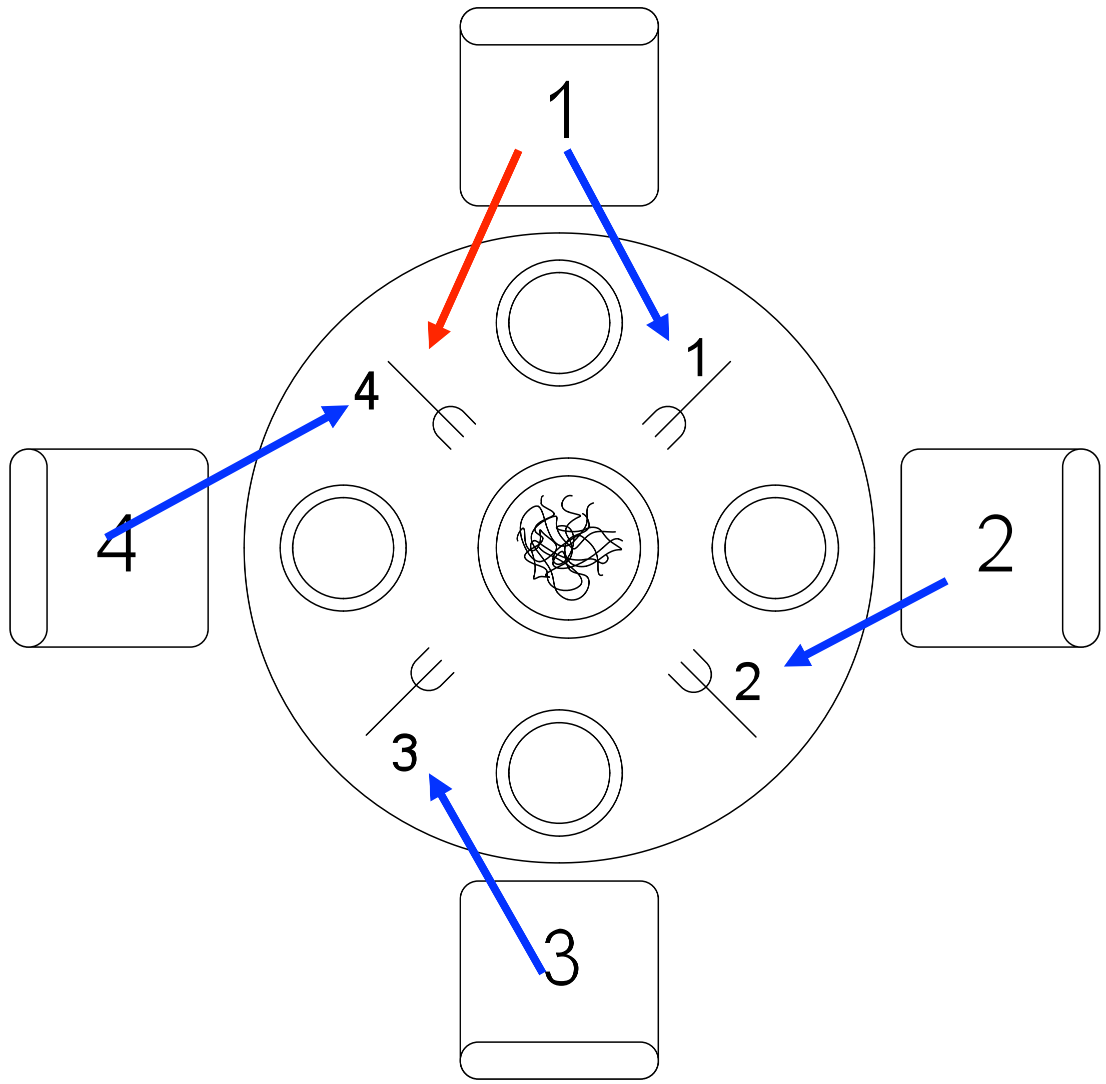

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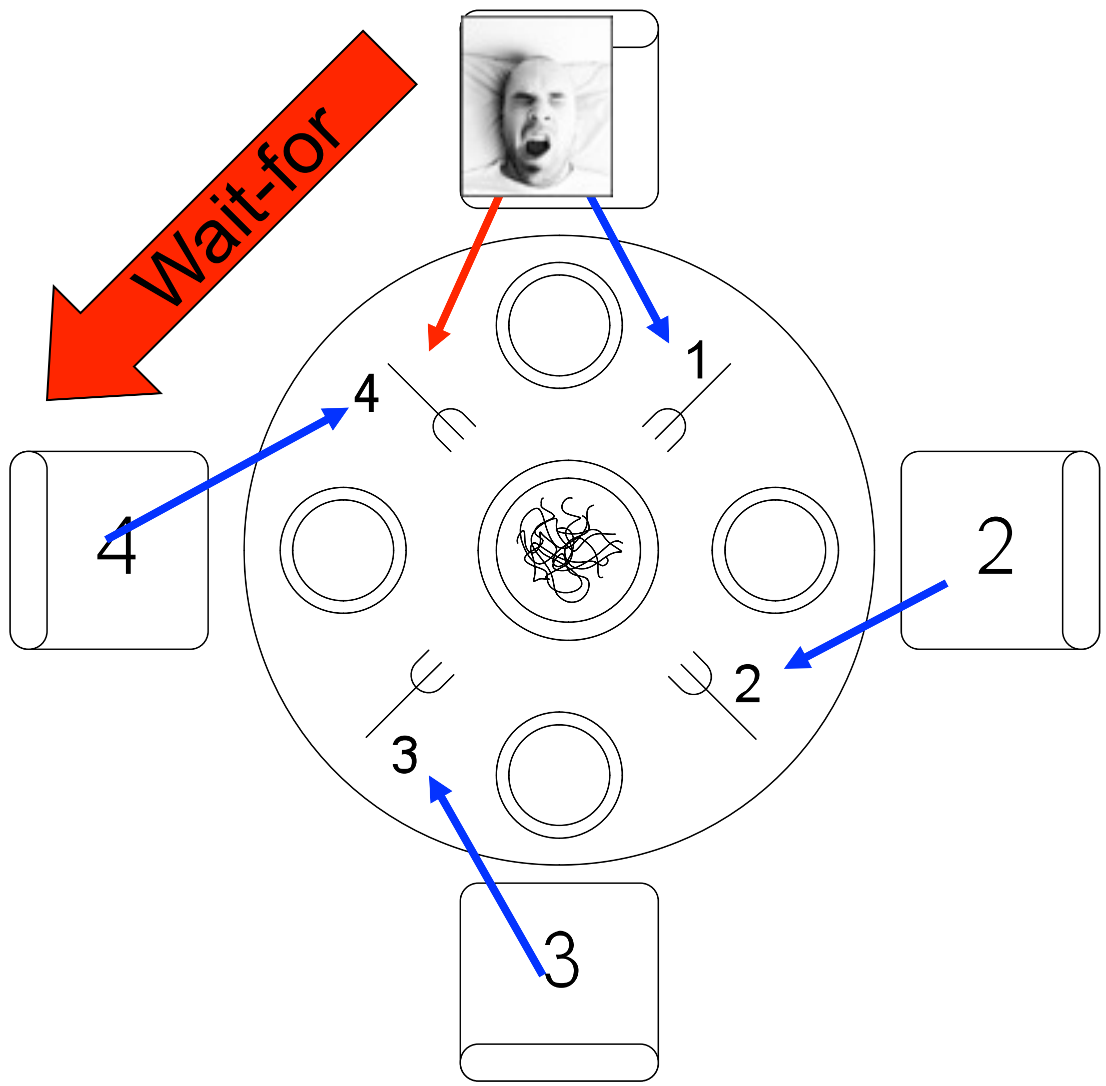

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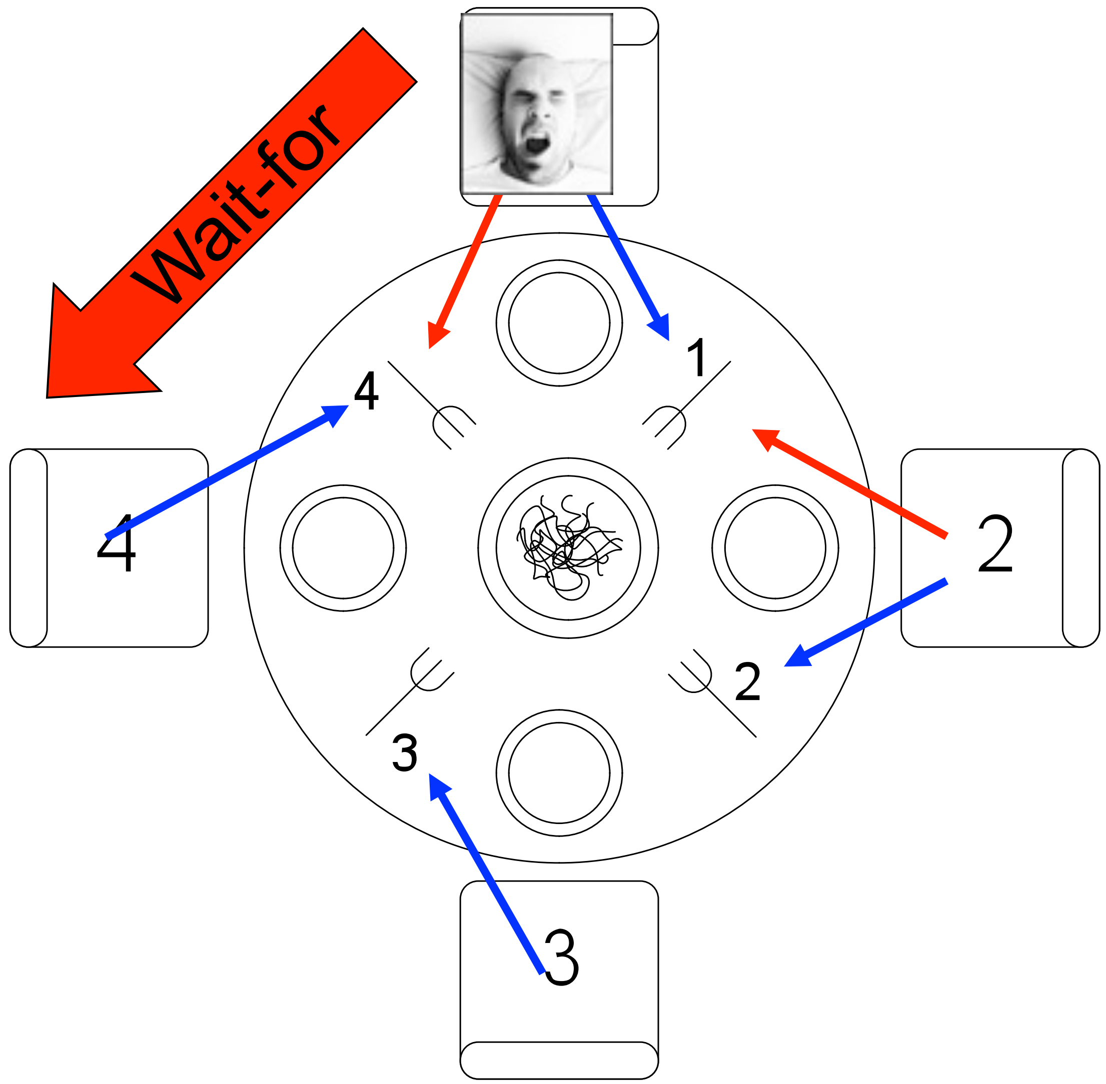

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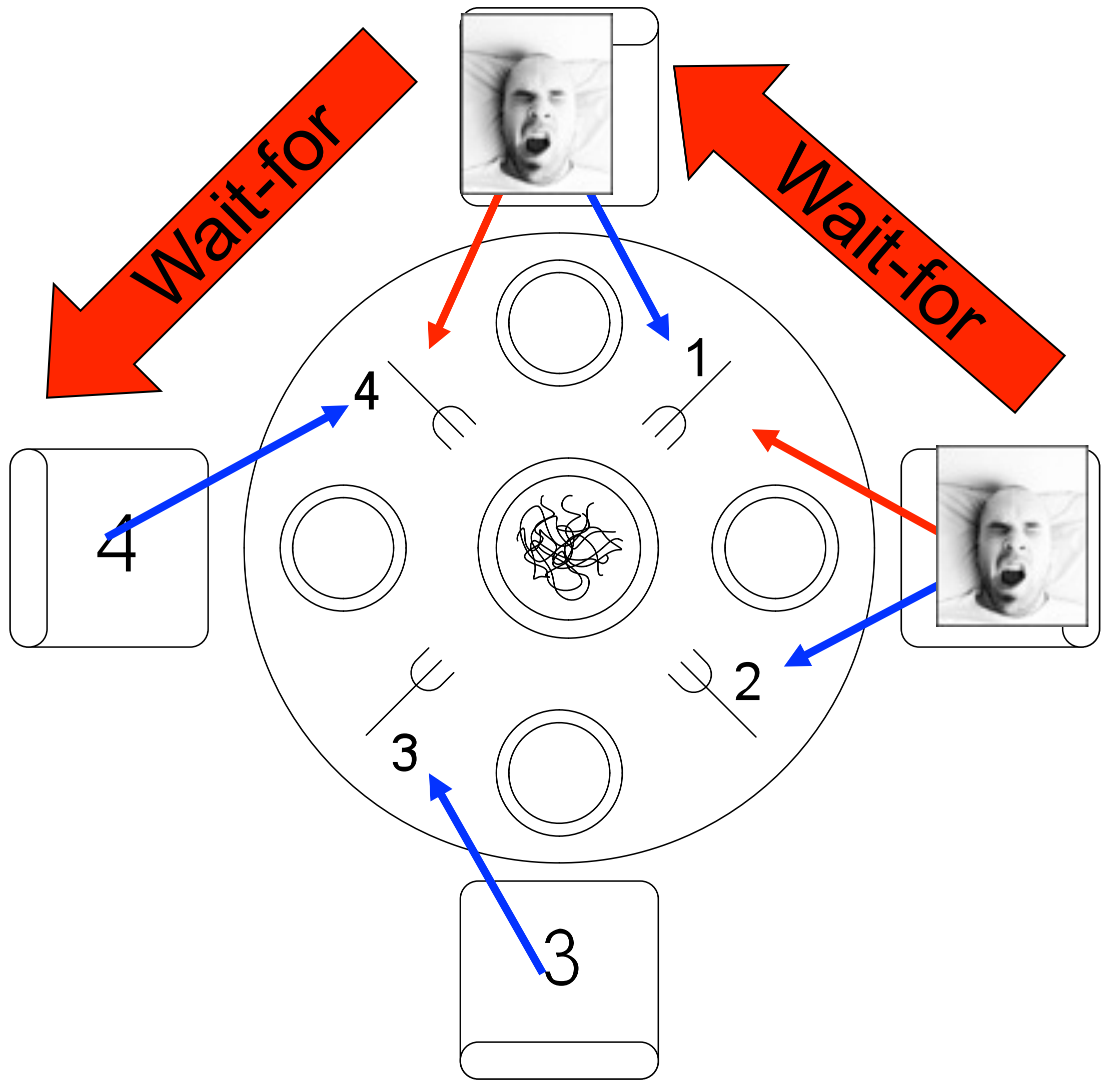

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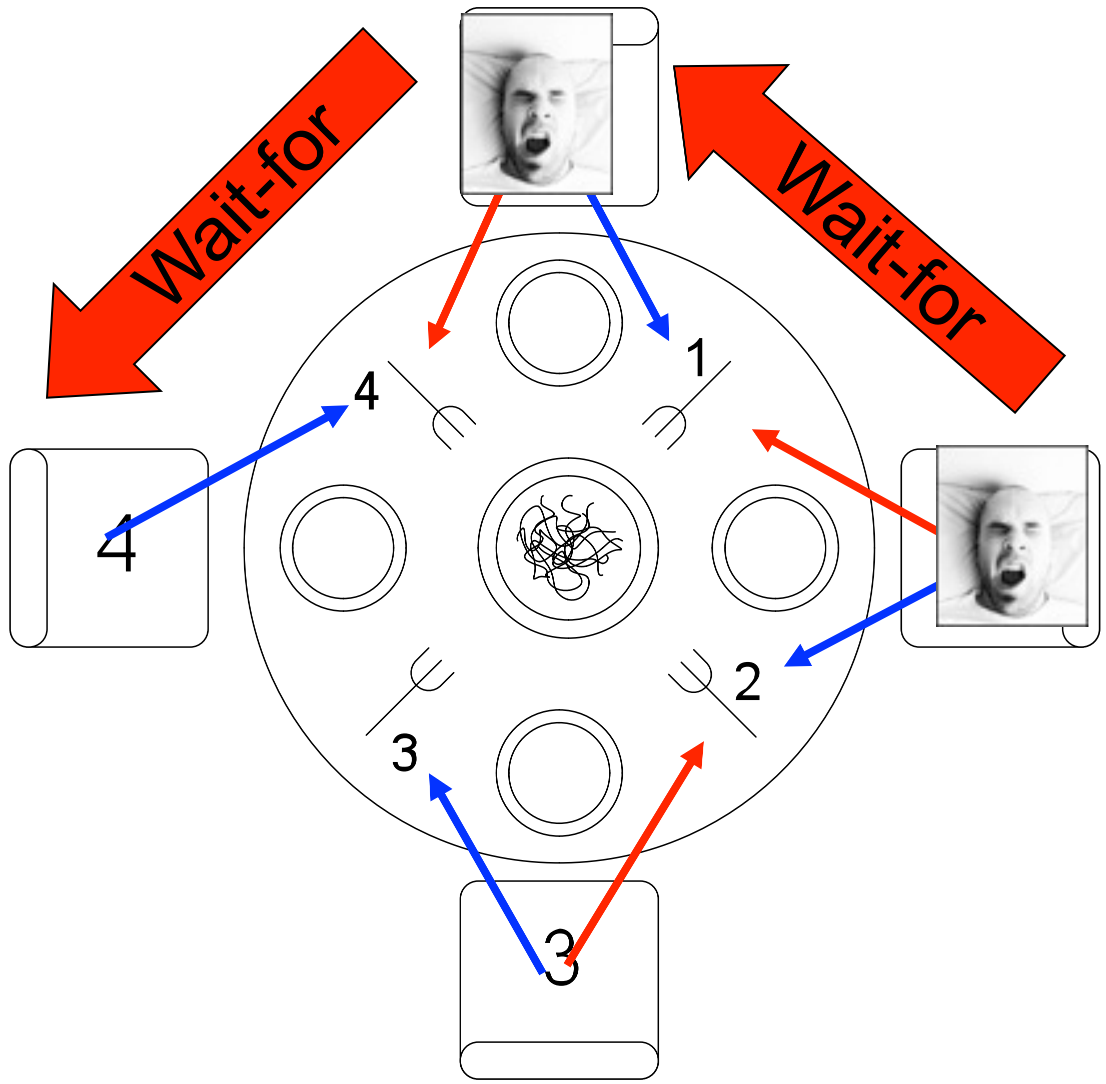

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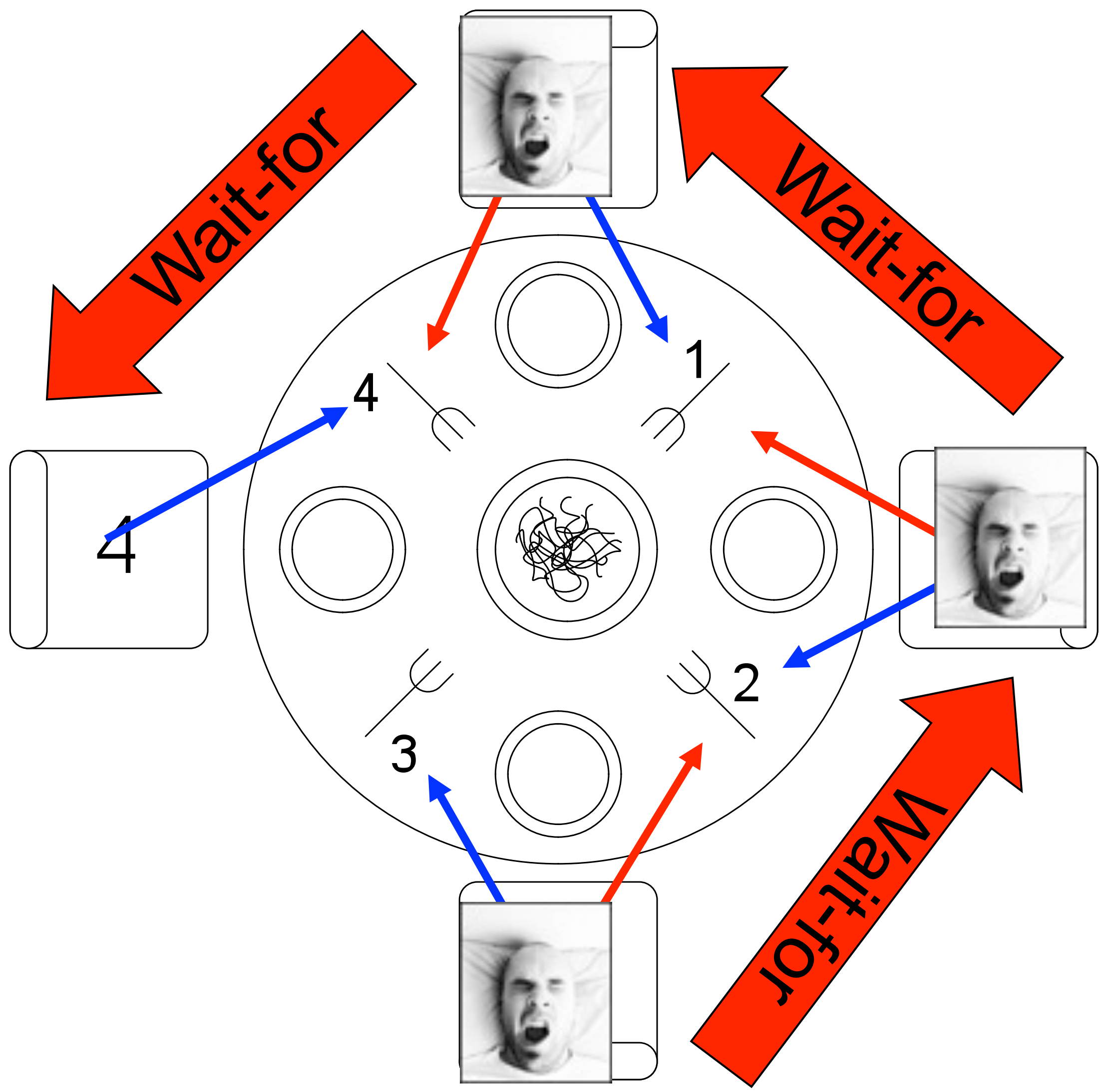

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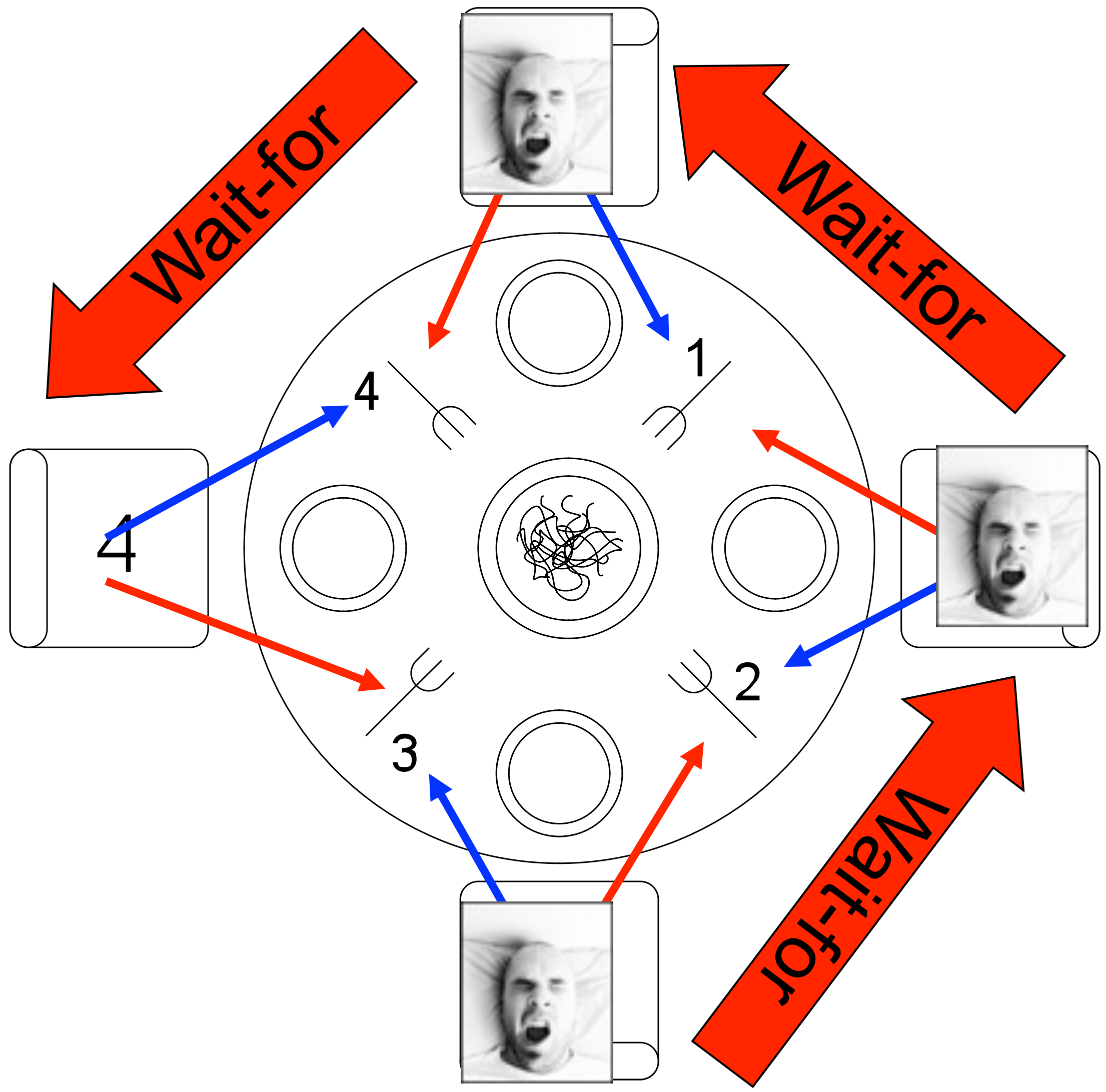

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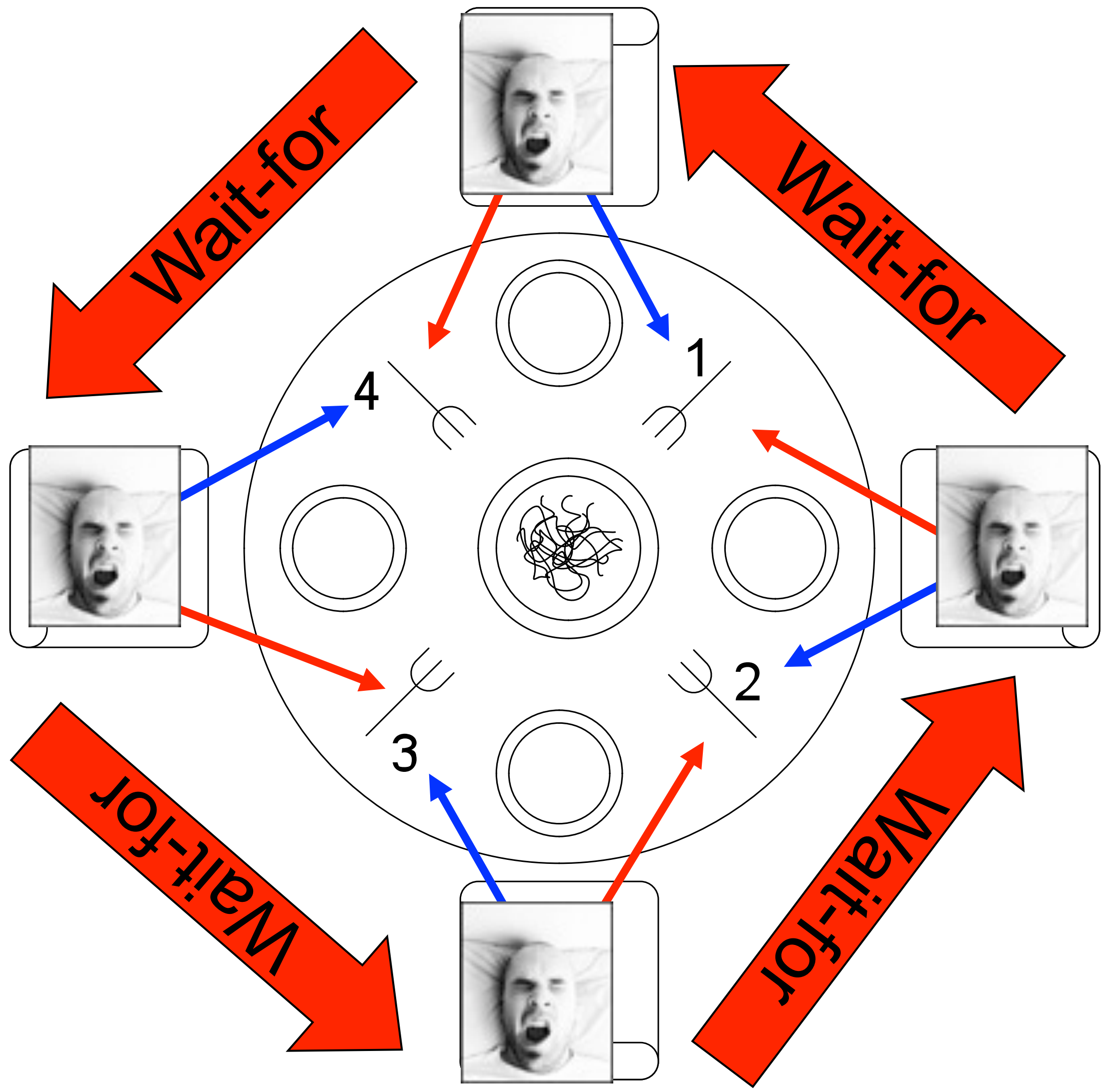

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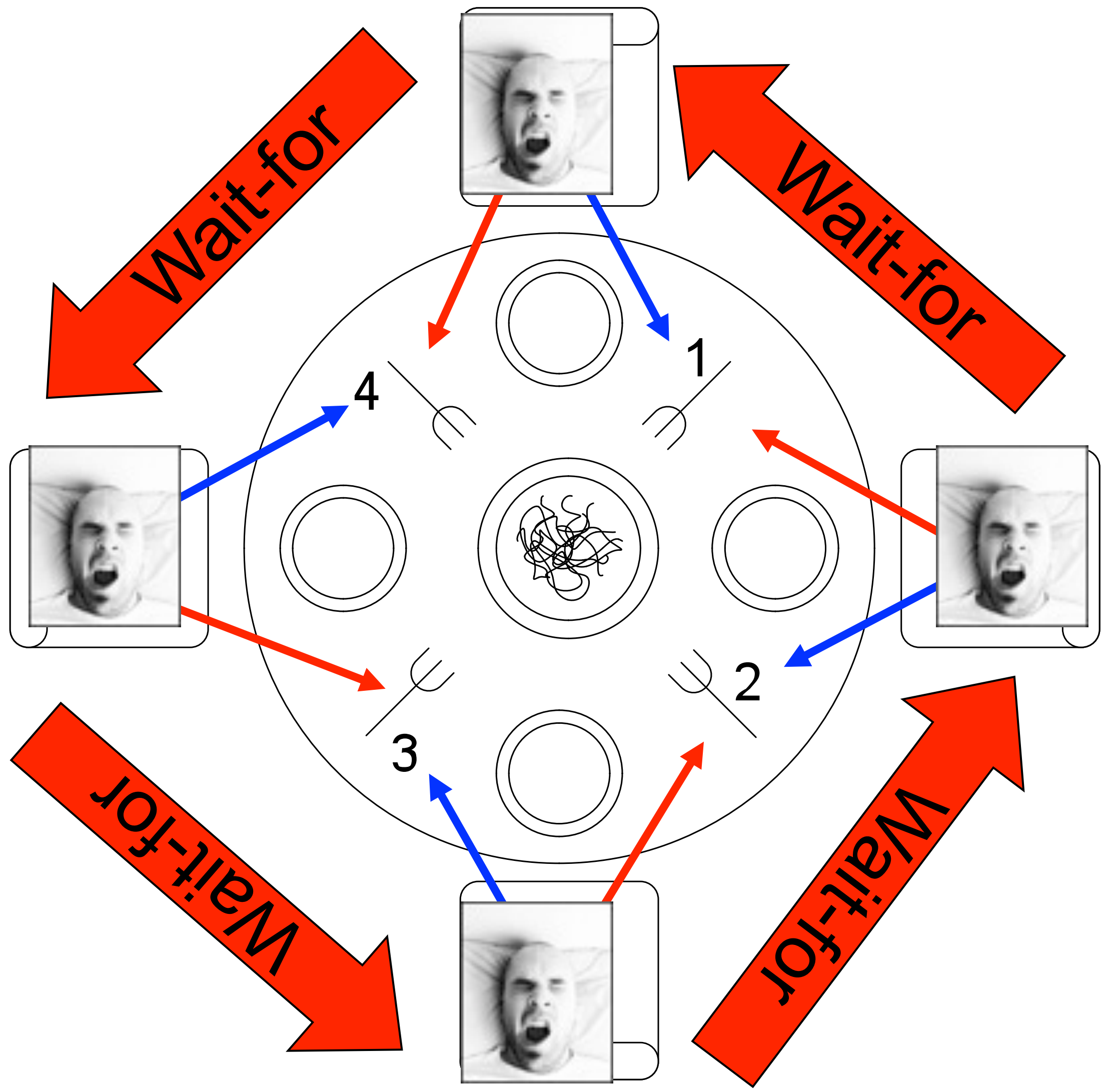

Deadlocks: Solutions

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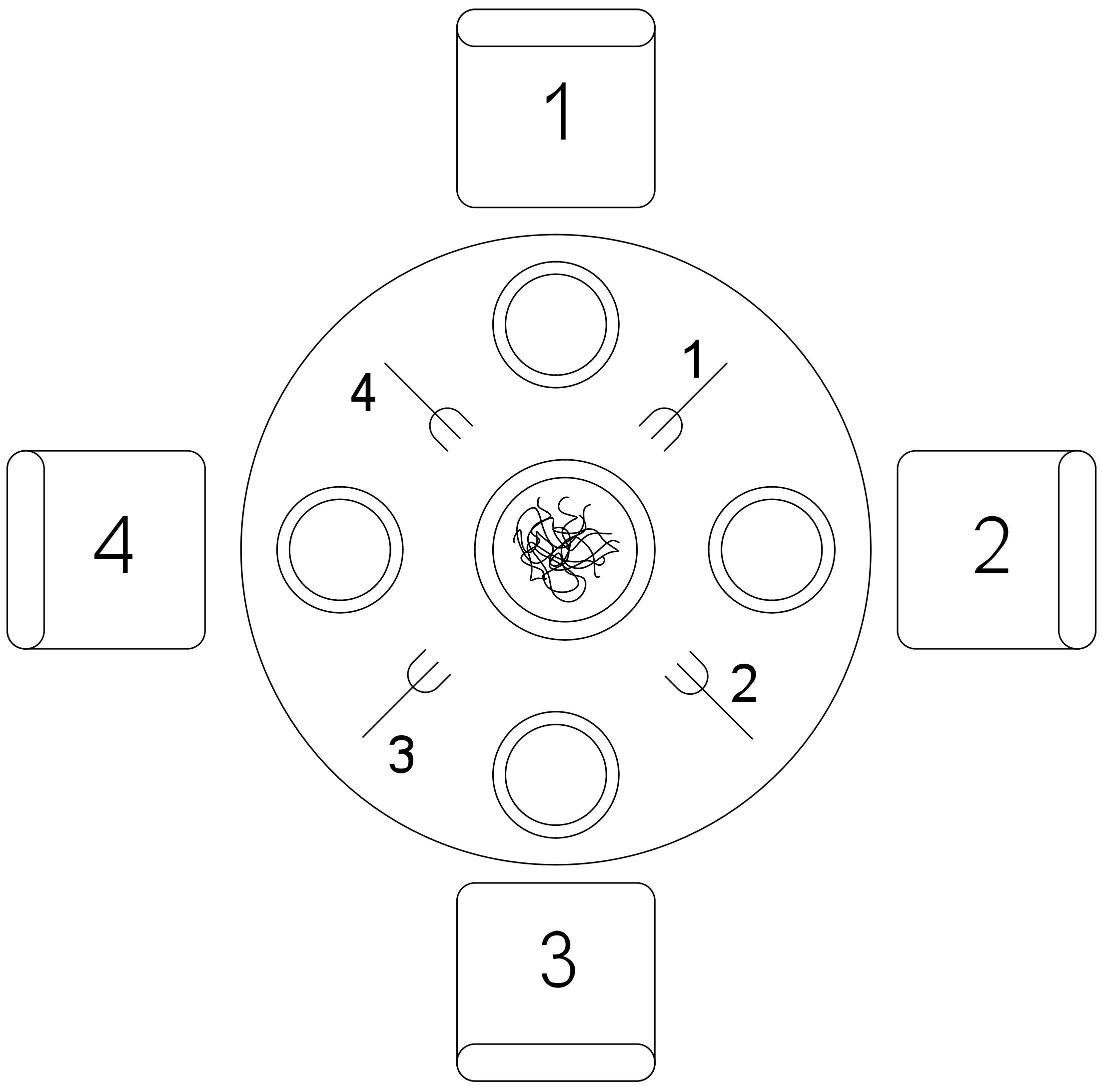
4? Yes…we can break the cycle!

Dining Philosophers - solution



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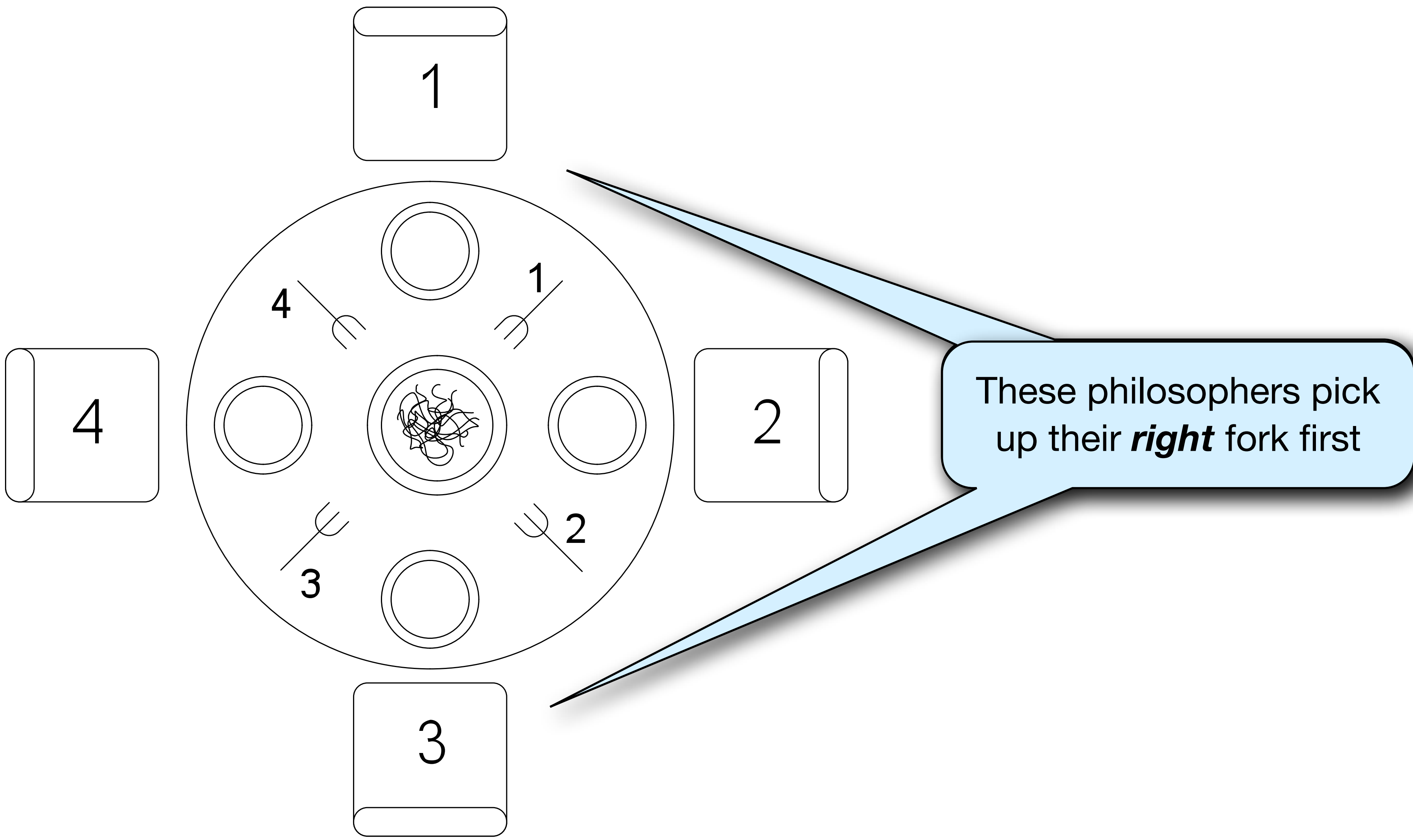

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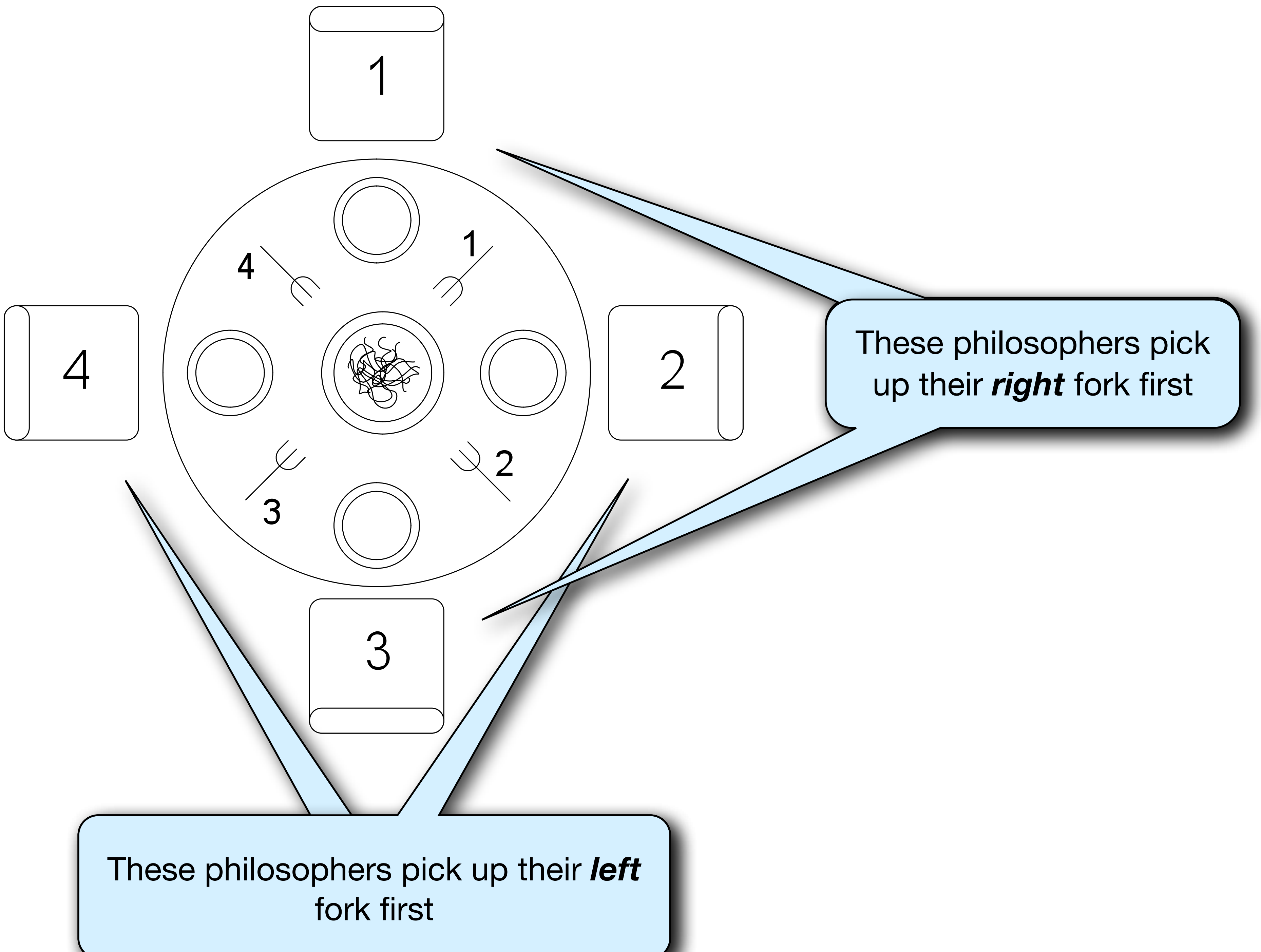

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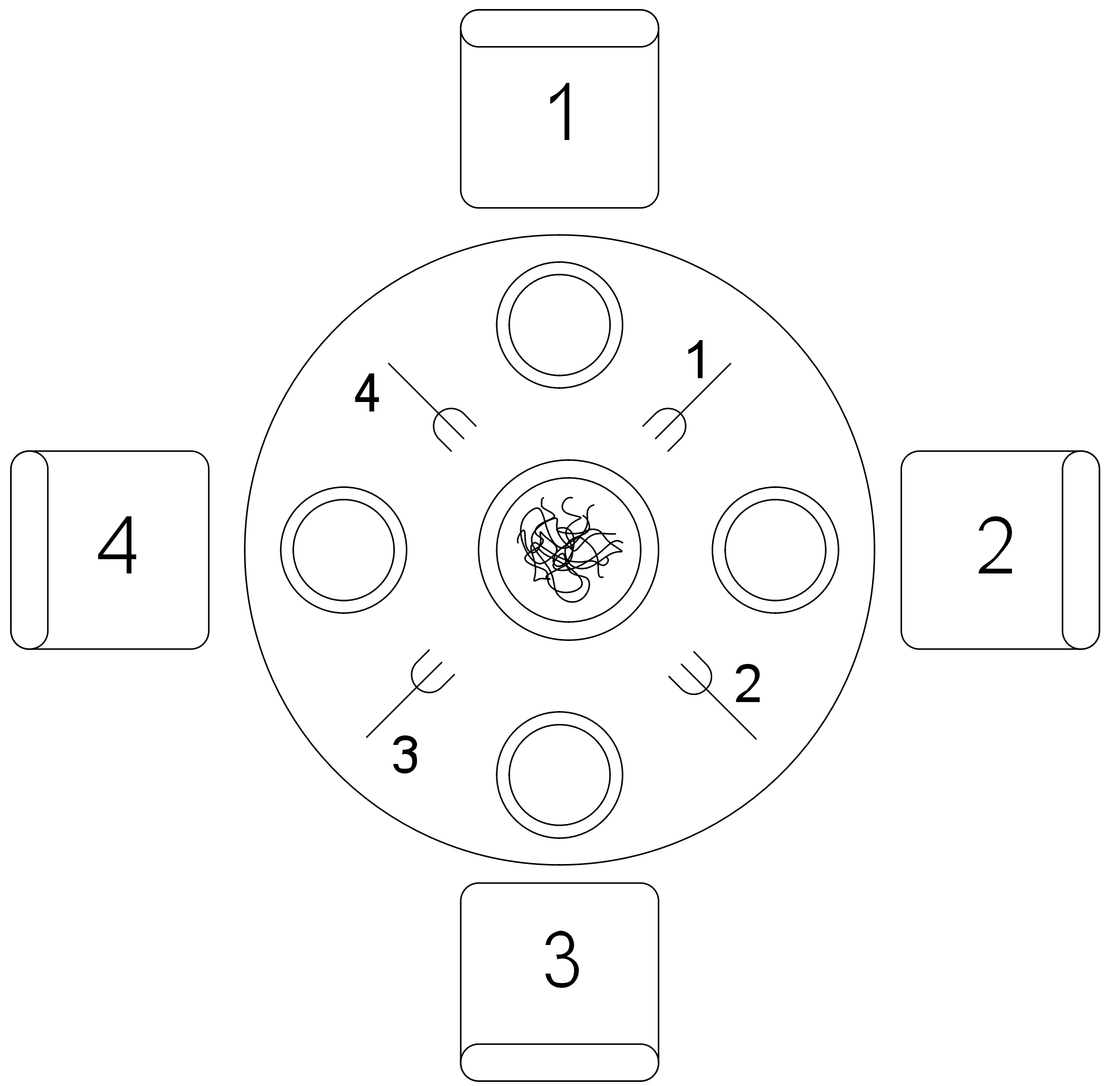
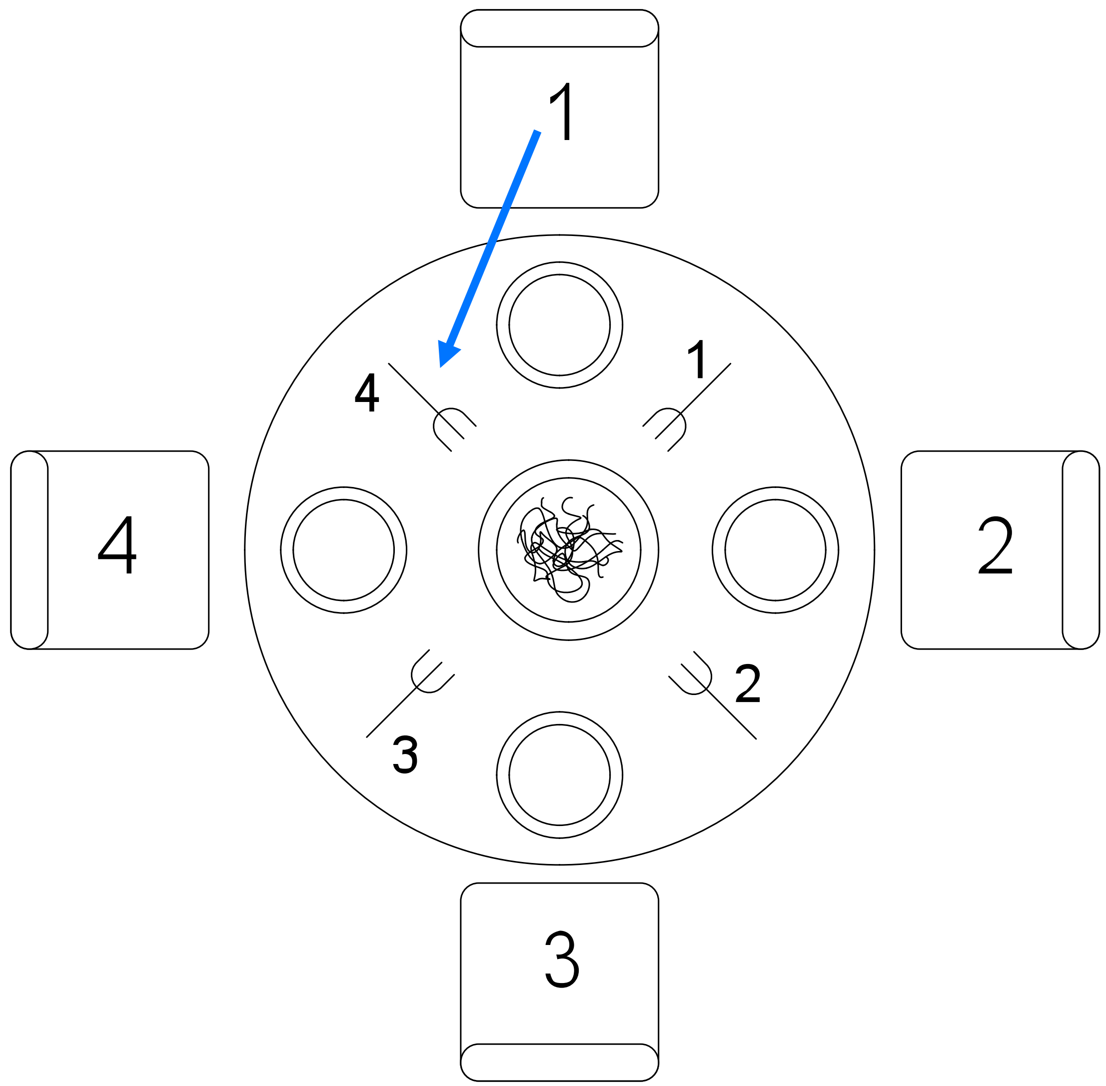


Deadlocks: Dining Philosophers - Solution



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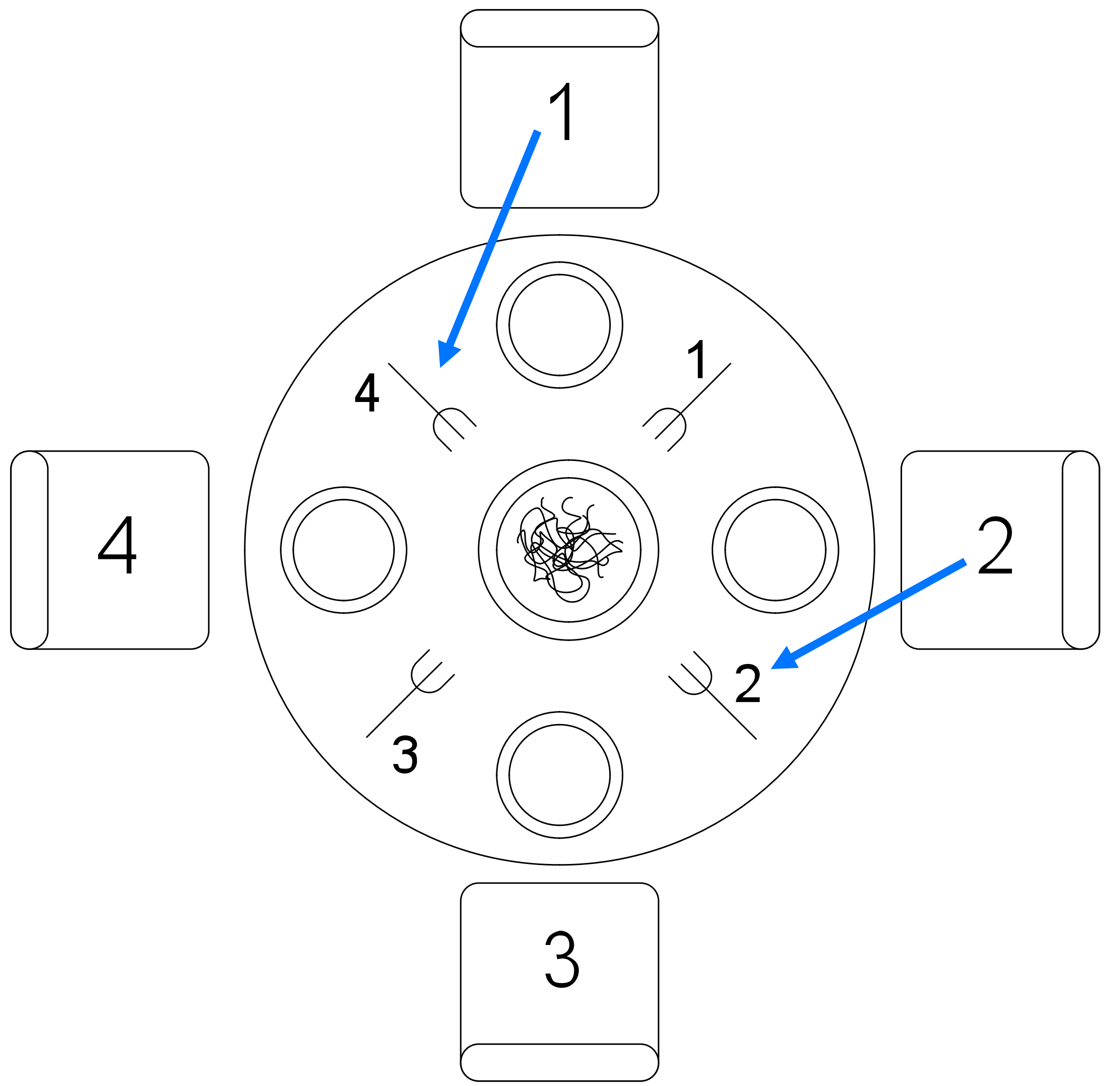

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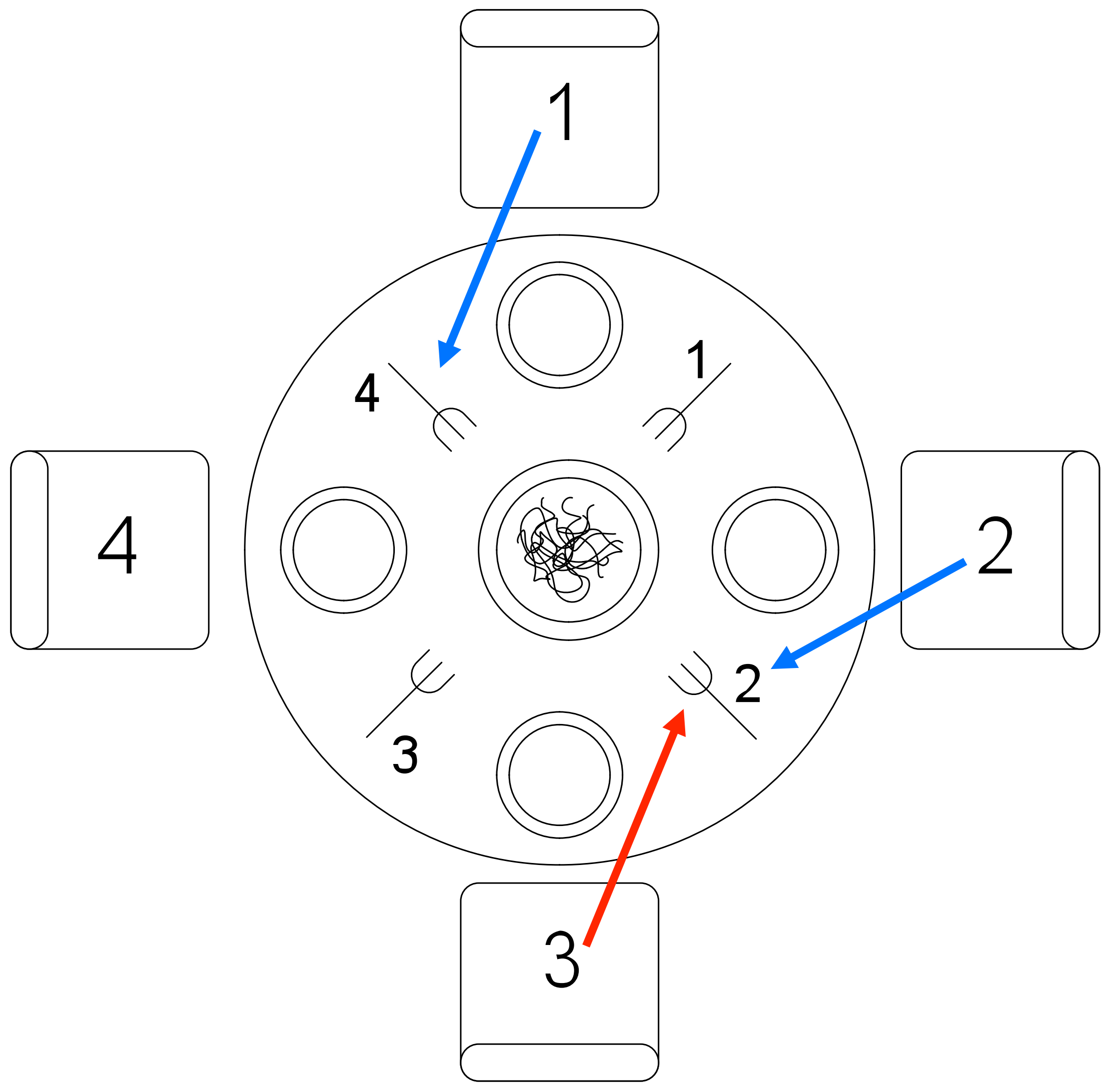

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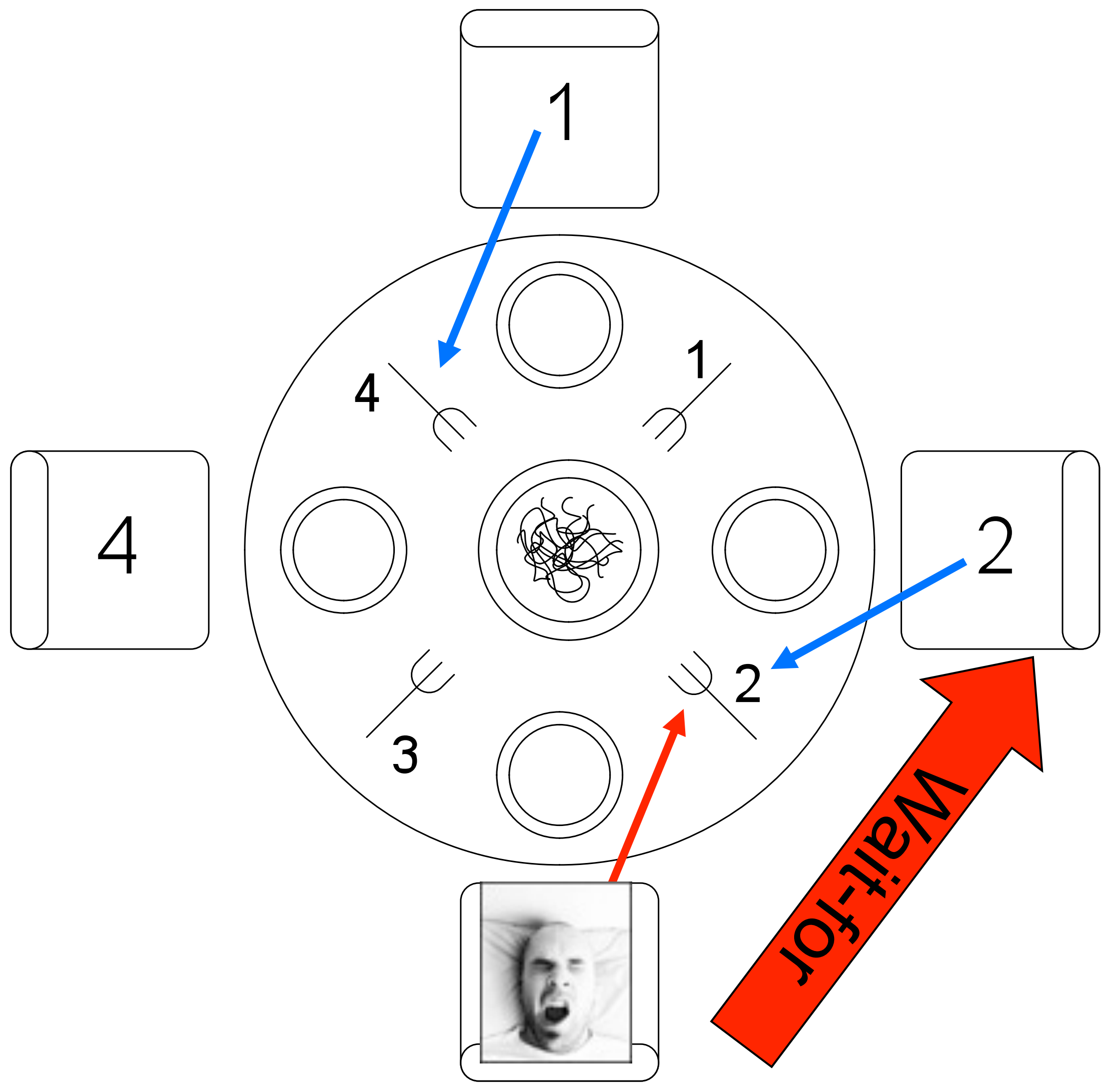

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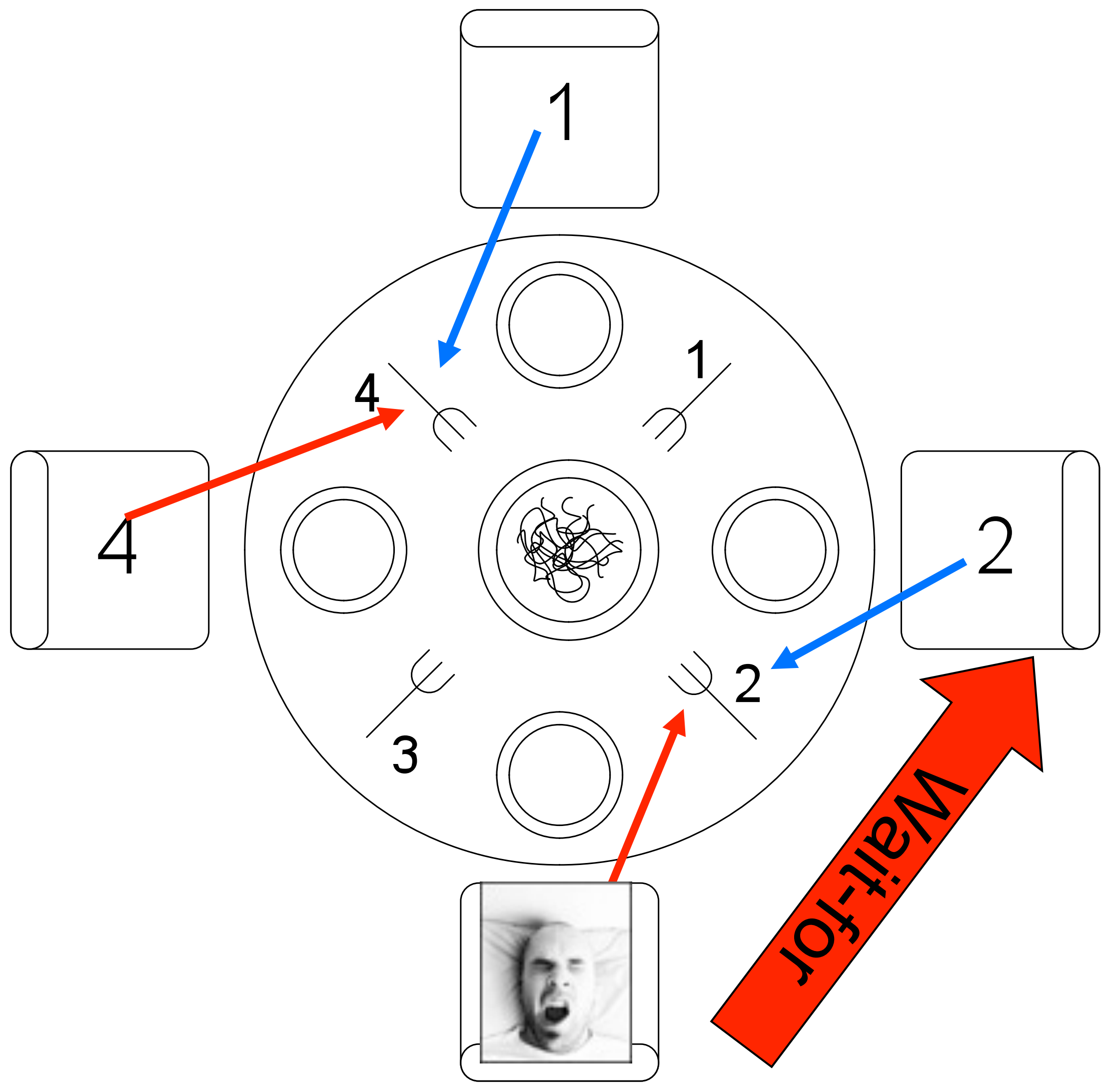

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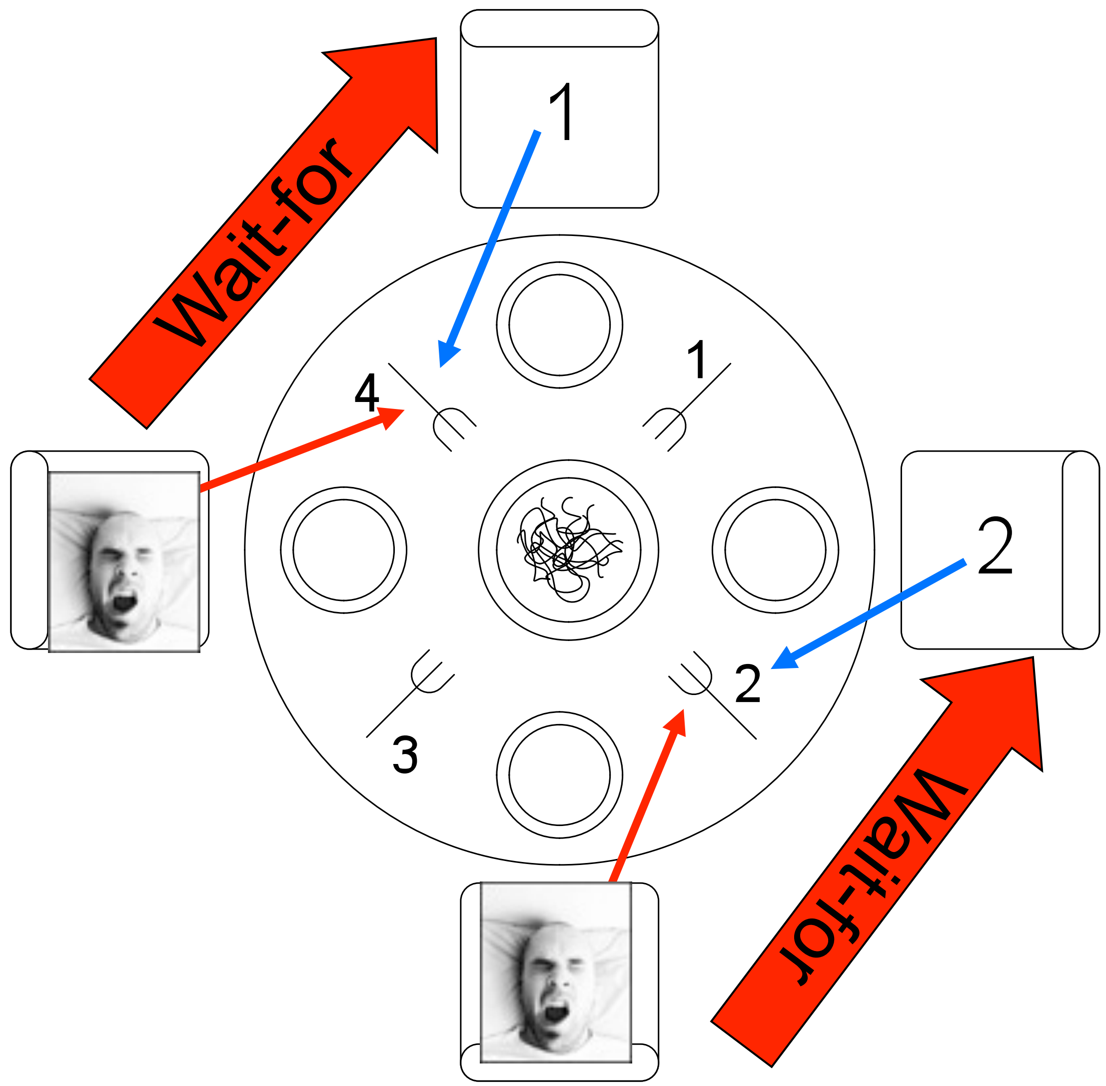

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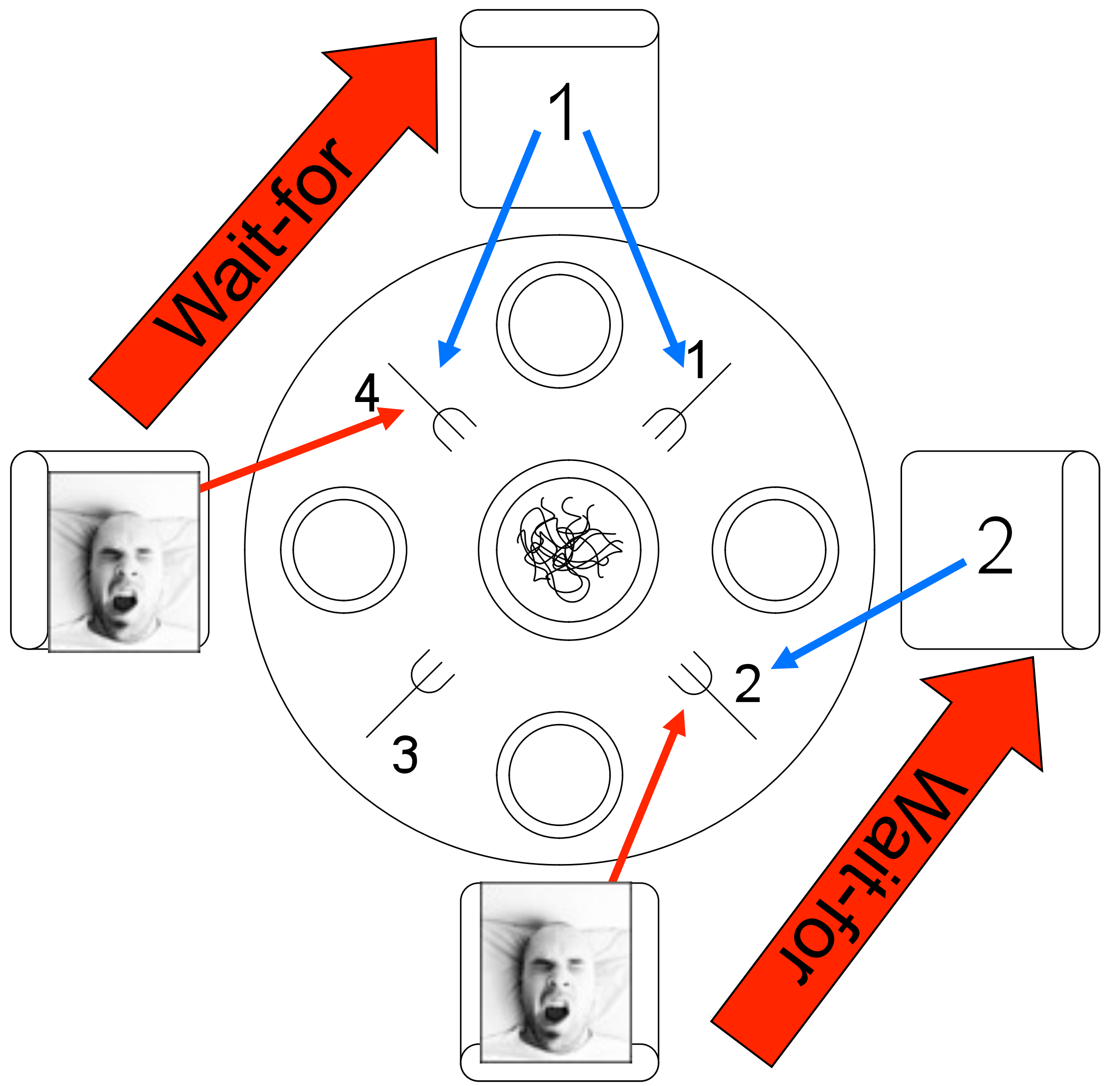

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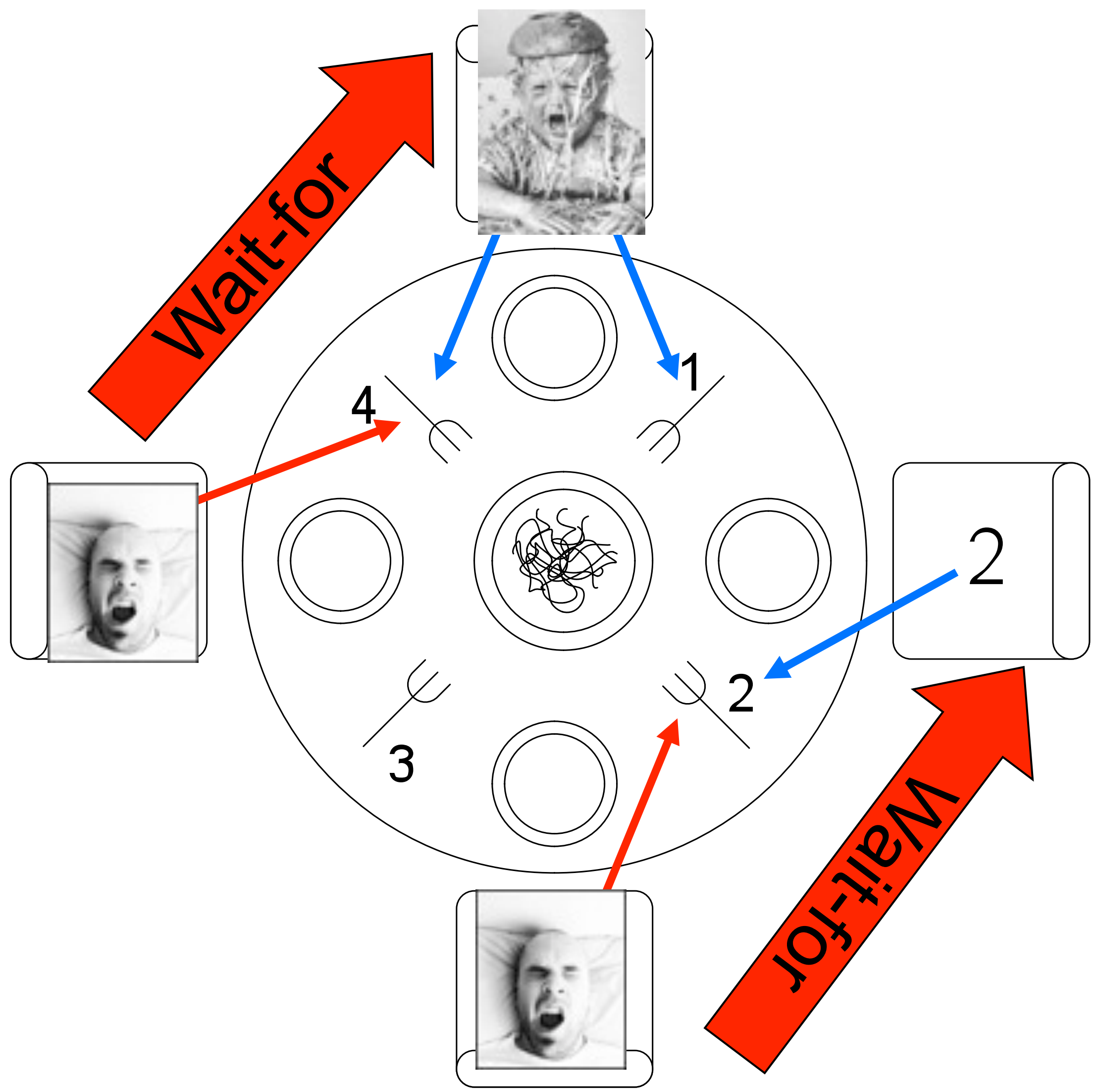

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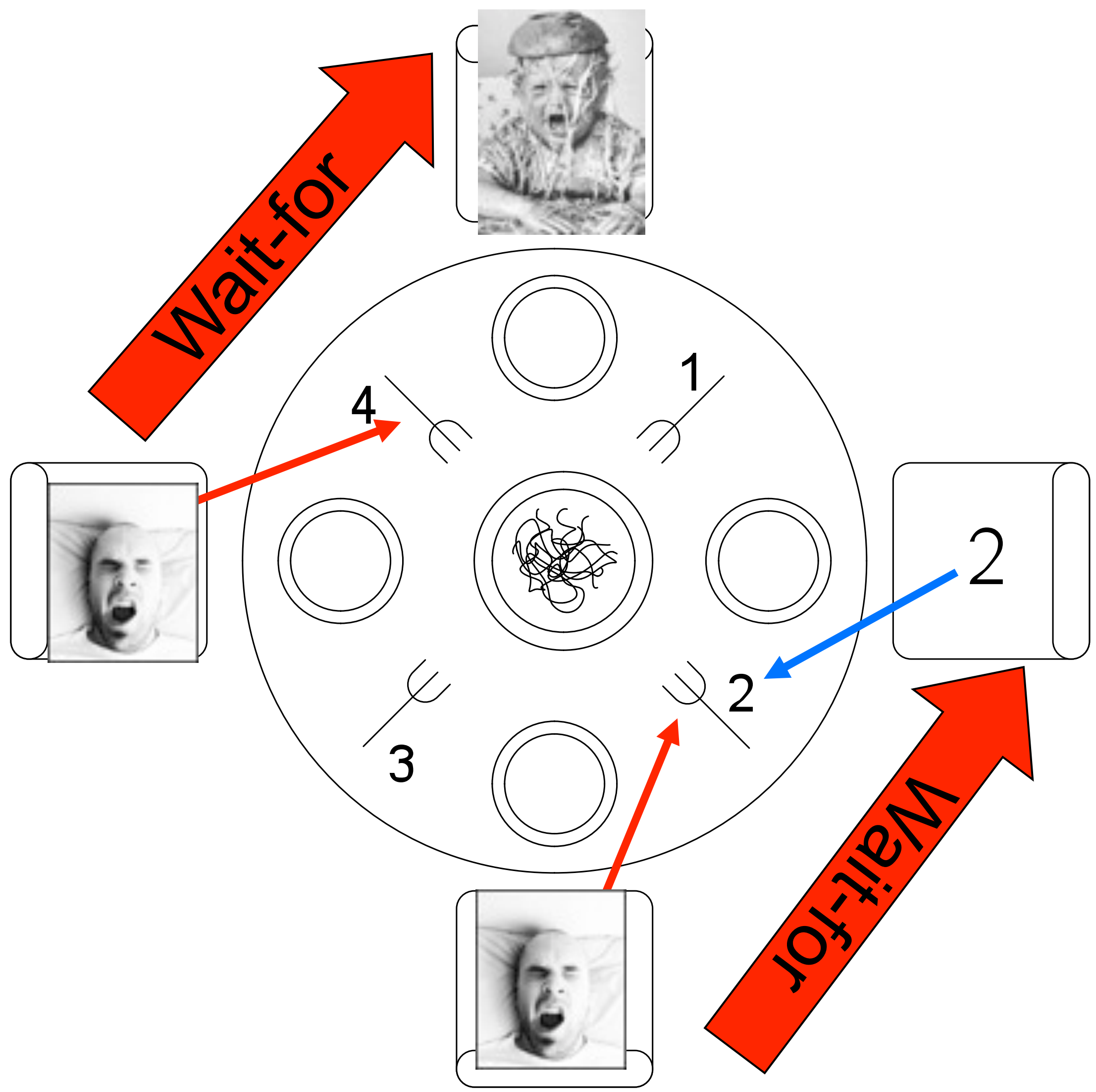

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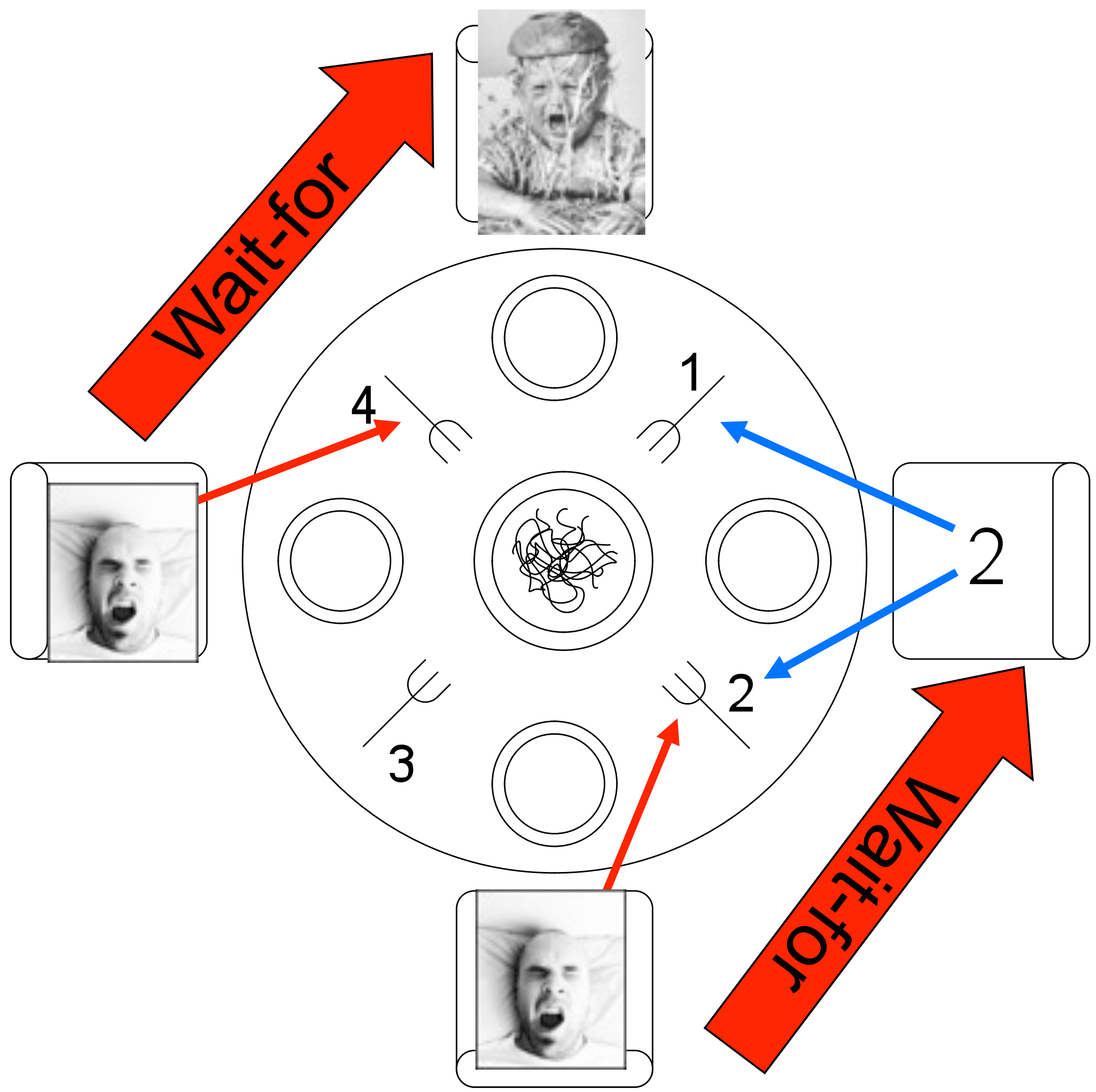

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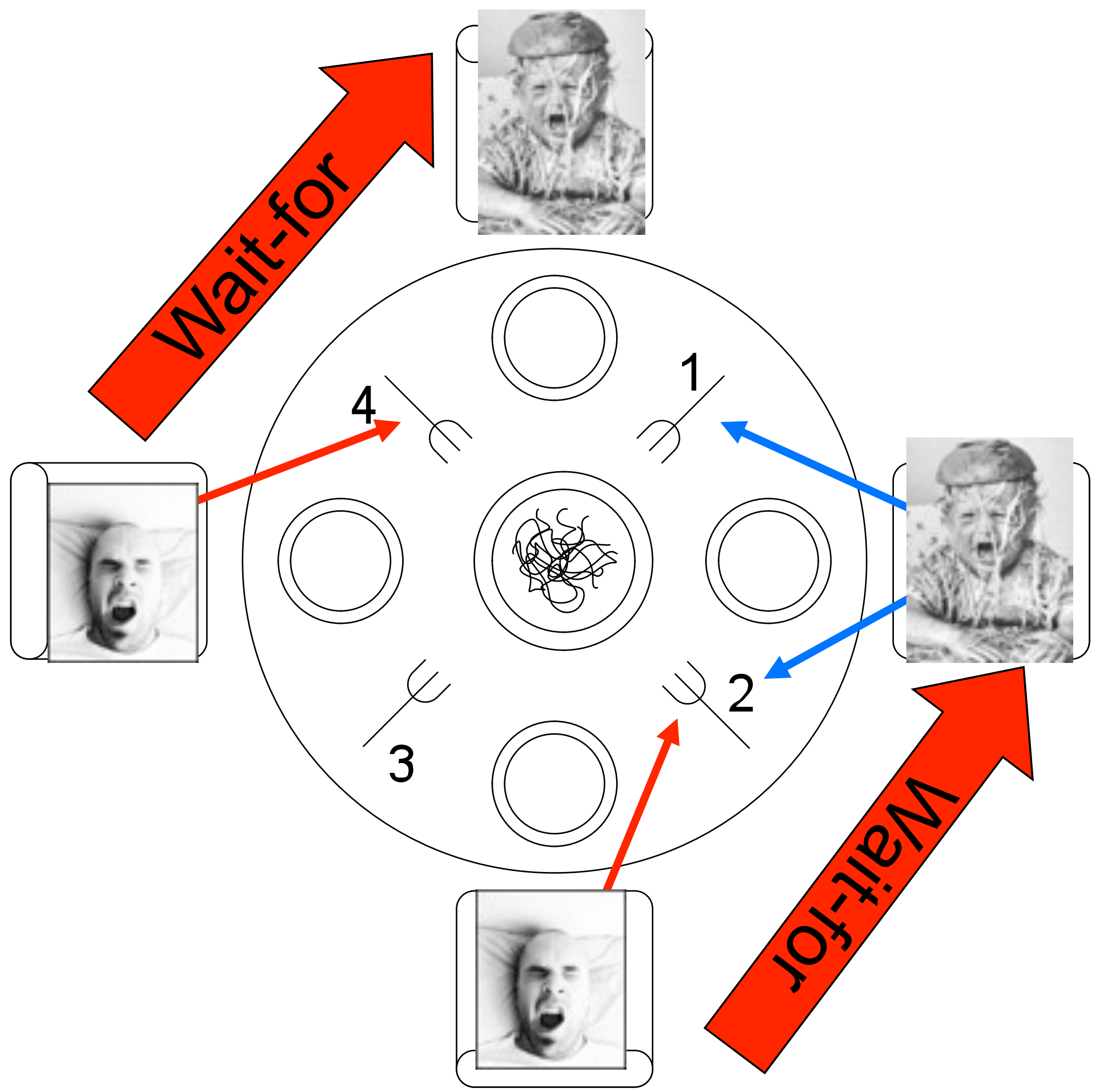

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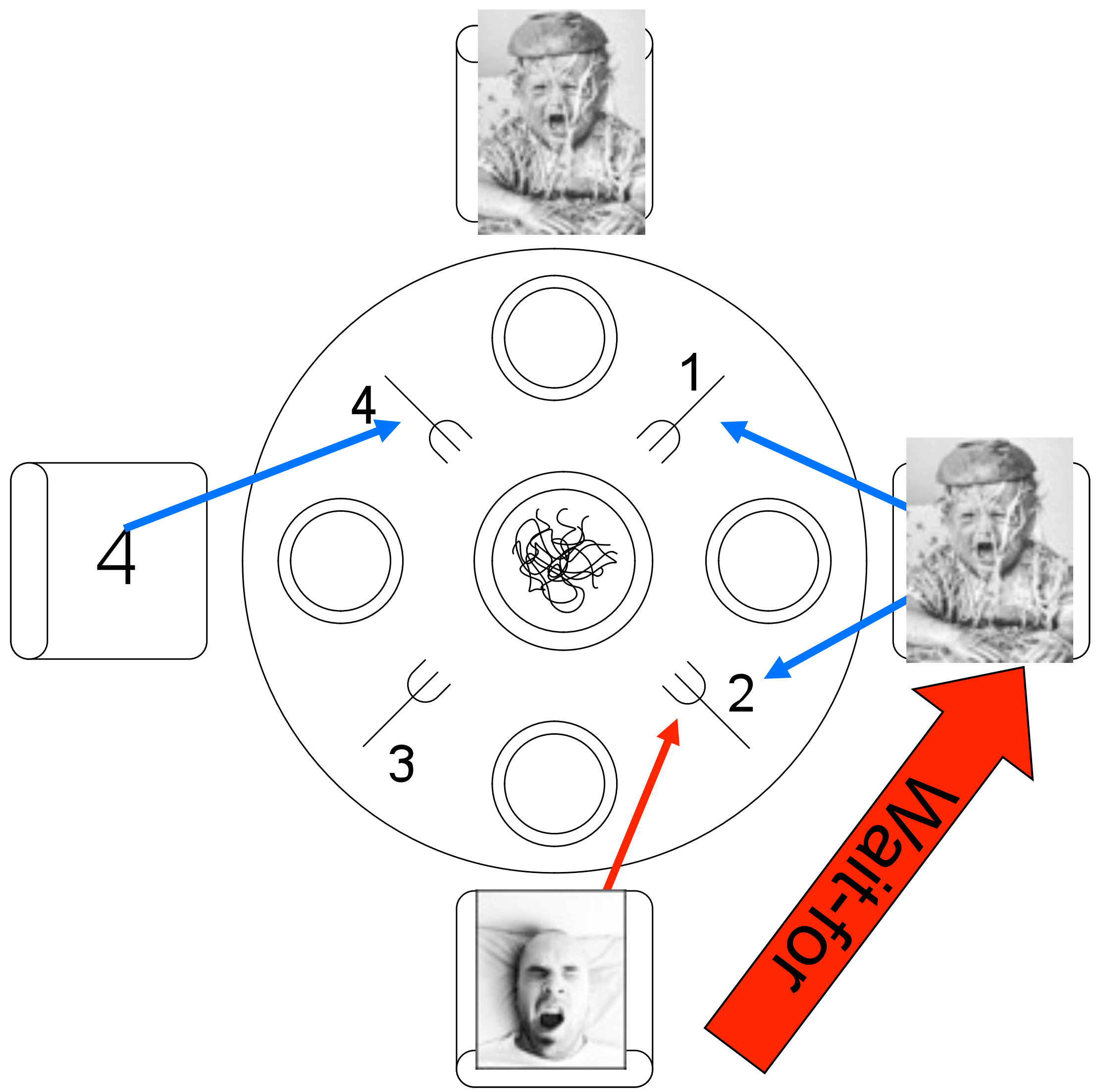

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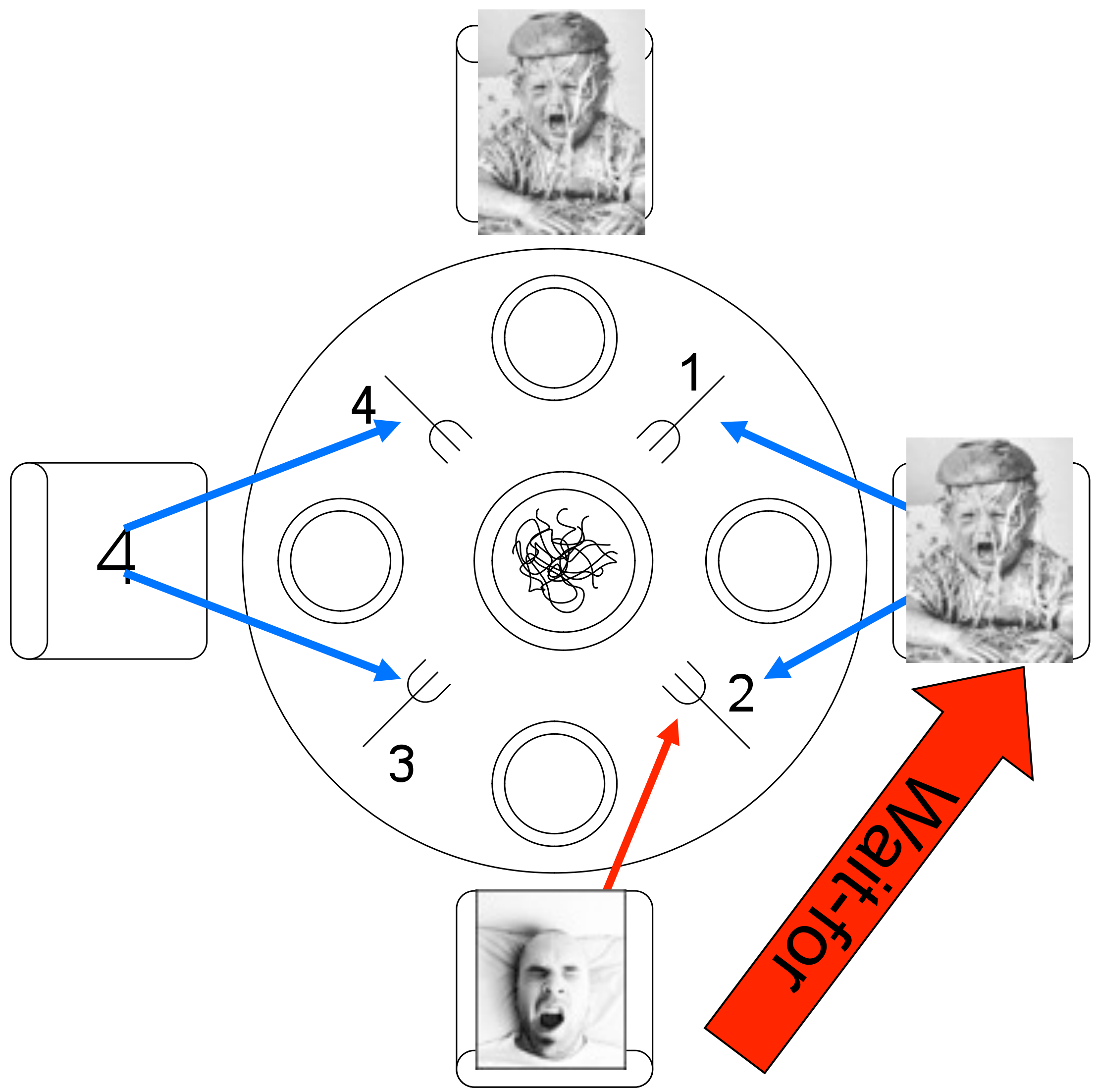

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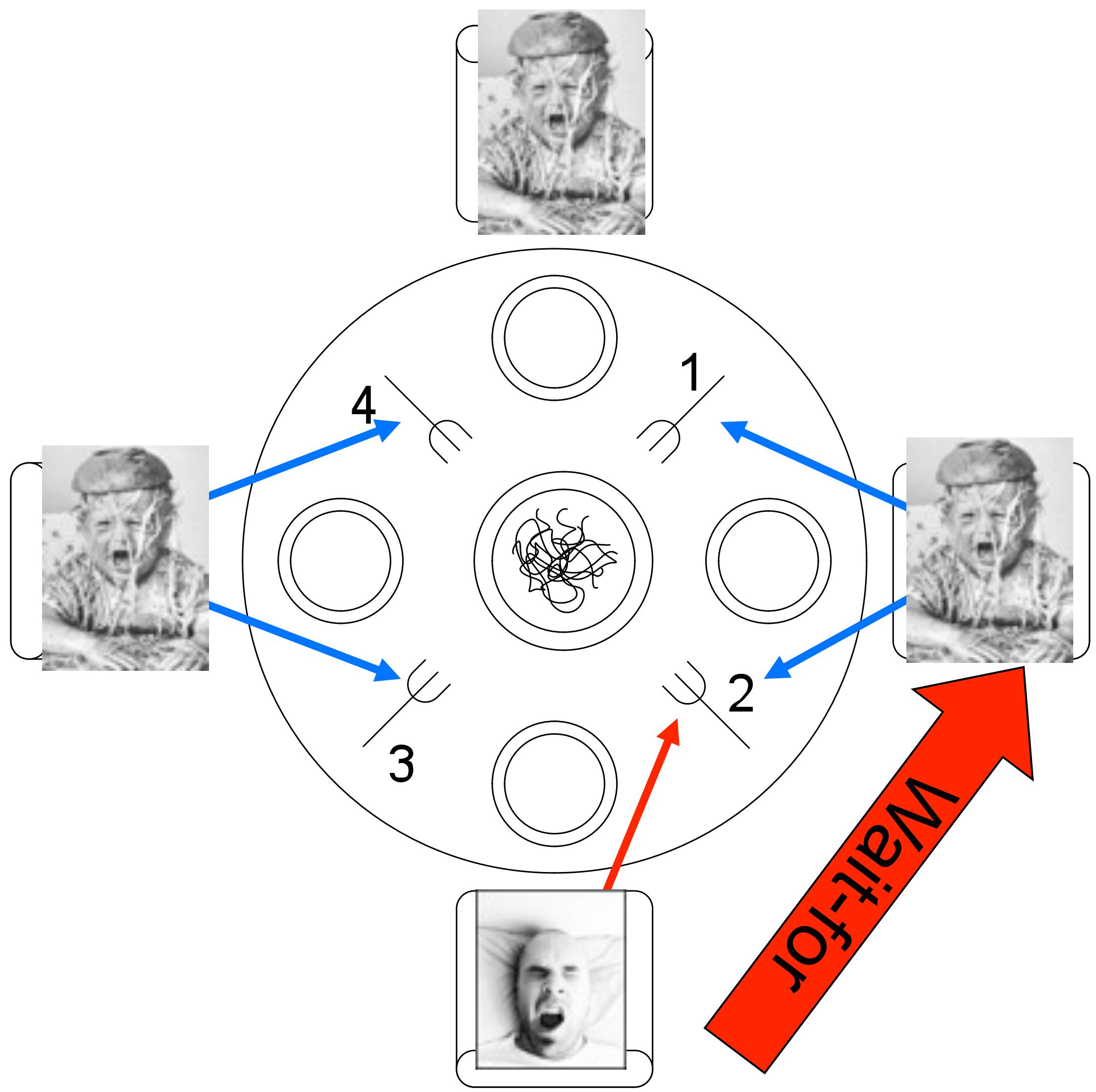

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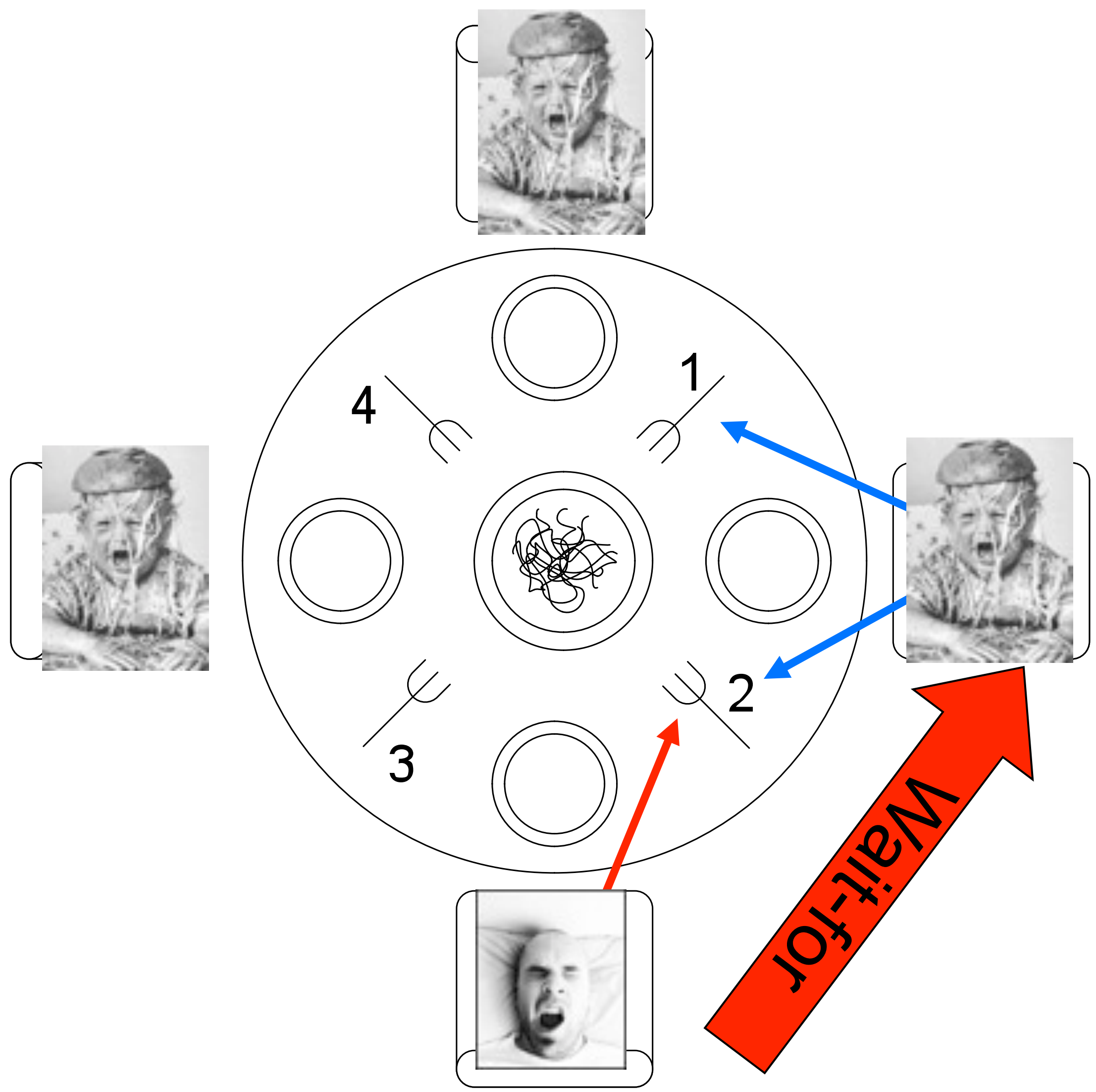

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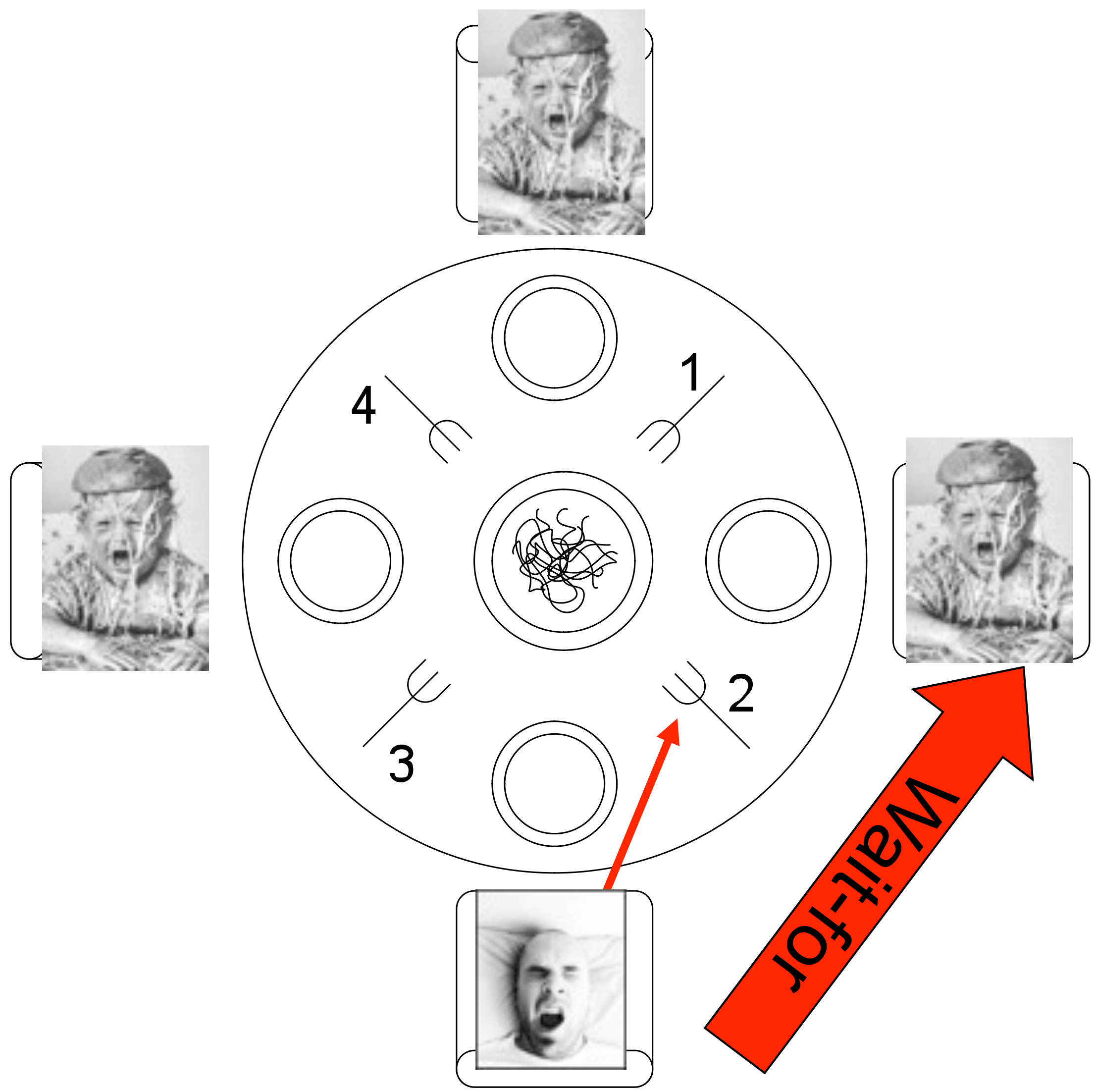

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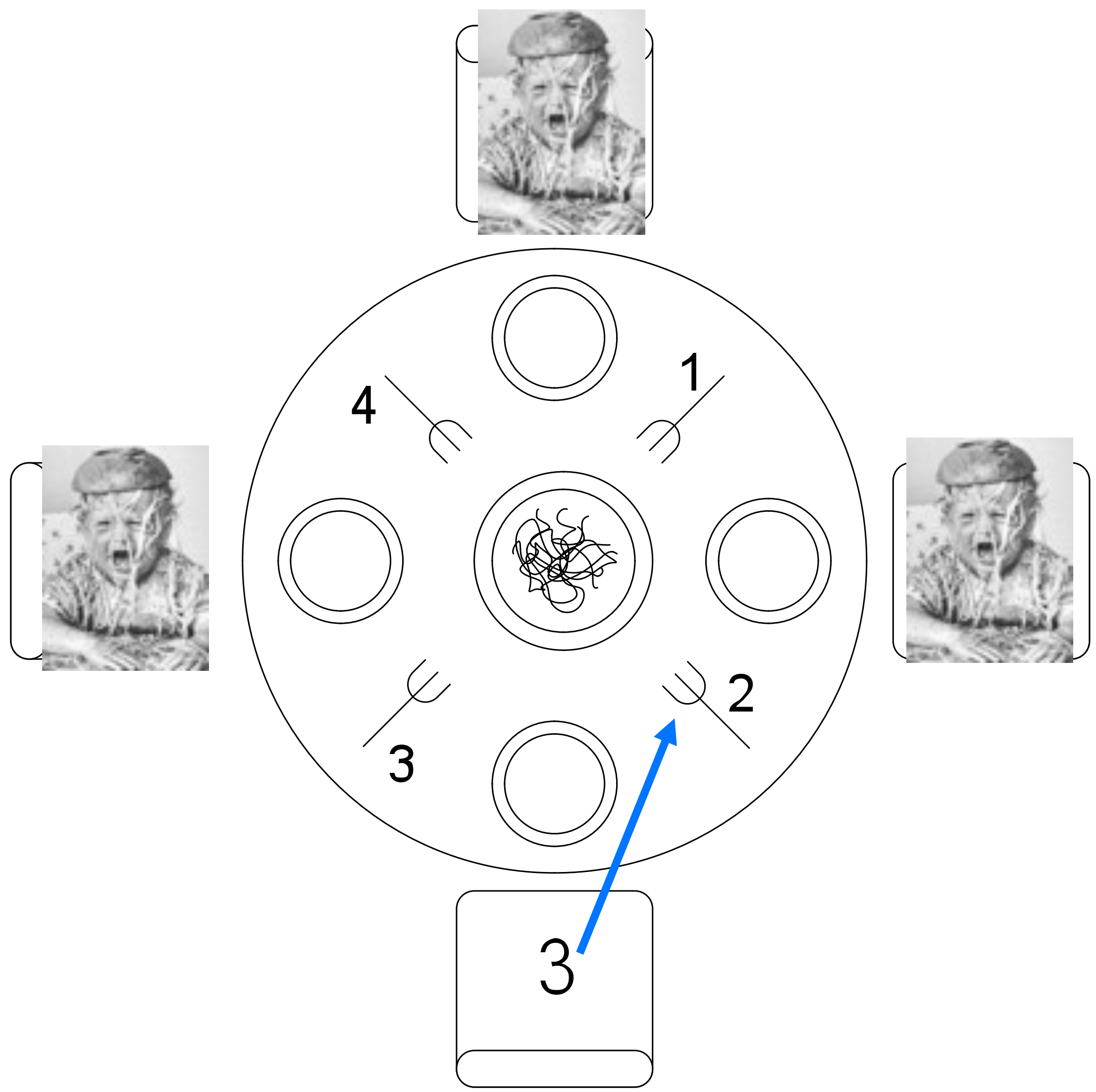

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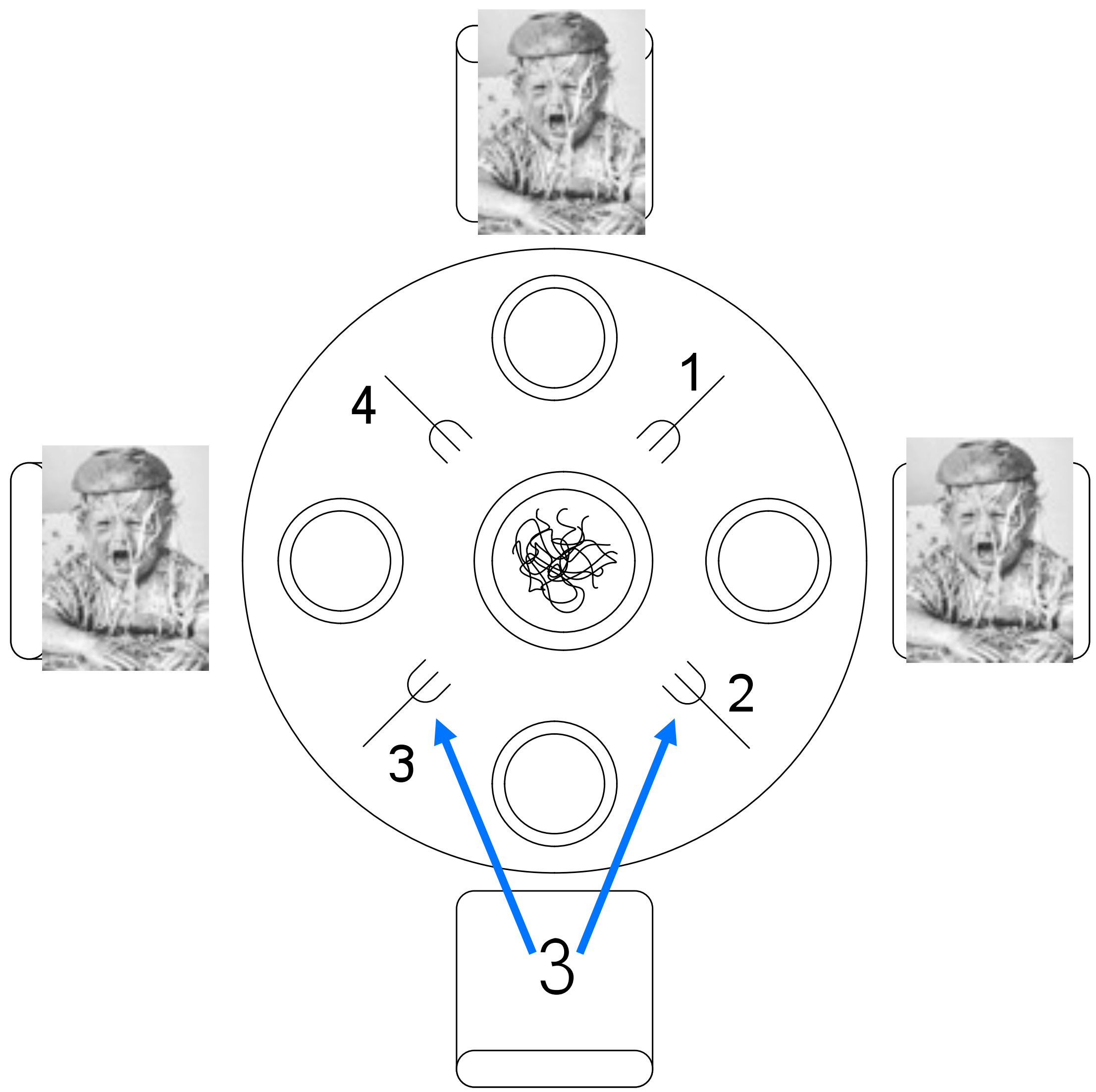

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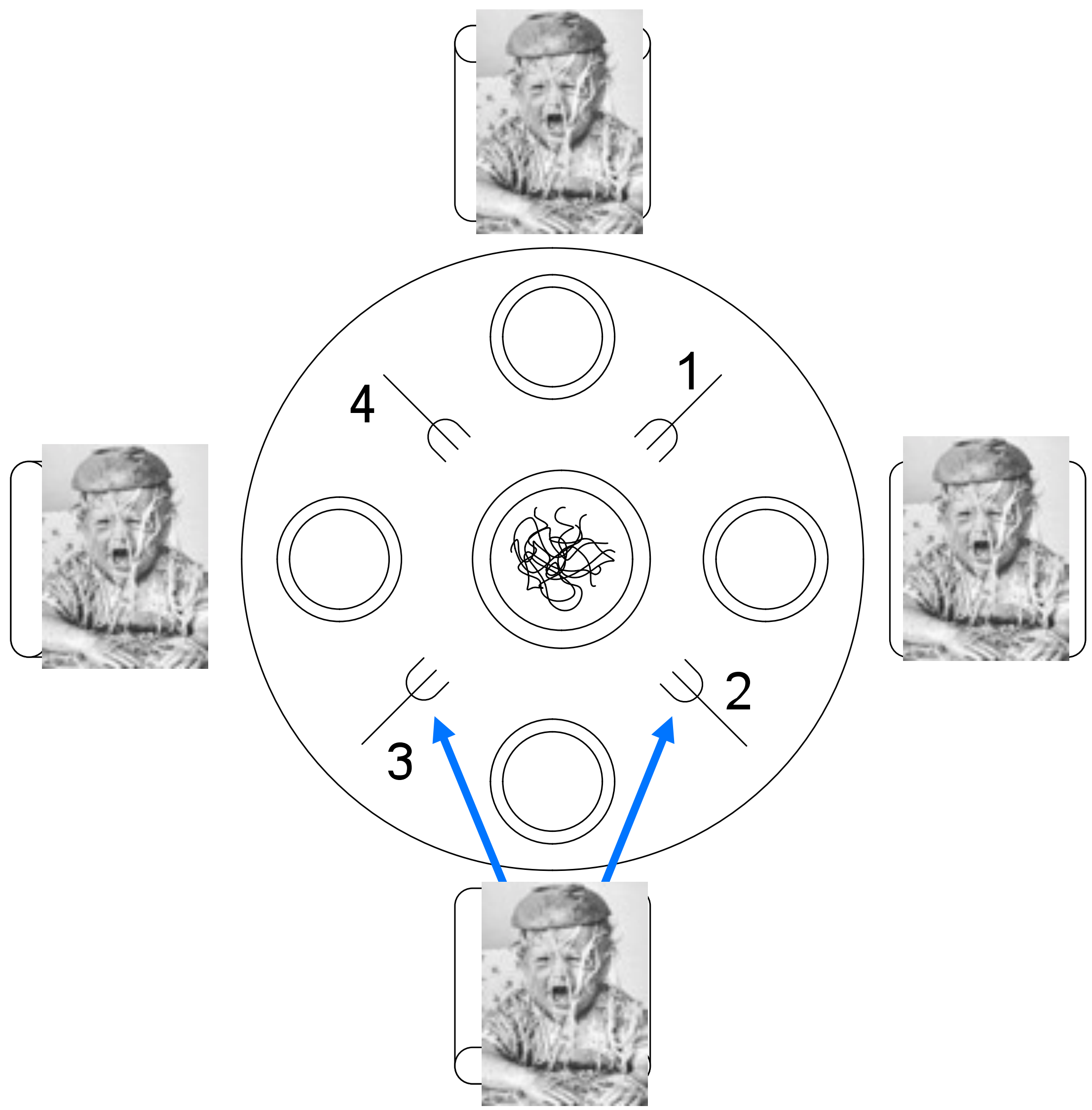

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